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A Rerolled-Bar Specification After years of waiting the manufacturers of concrete reinforcing bars rolled from old rails have been given a specification by the American Society for Testing Materials, the passage of the specification to letter ballot at last week's meeting virtually assuring its adoption, especially since there was not a word of dissent. This leaves only the American Railway Engineering Association excluding the rerolled bar, for the Association of American Steel Manufacturers early this year also adopted a specification admitting these bars. While the feeling favorable to rerolled bars has been growing, the willingness of the manufacturers of this product to abide by an impartial investigation to determine whether the uniformity was great enough to enable a satisfactory specification to be drawn indicates their ability to stand on the merits of their product. That their position was well taken has been proved by the excellent report of Professor Hatt on his investigation of this particular question. Undoubtedly there will still be opposition to rerolled bars, but if the latter pass the specifications considered last week at Atlantic City the only legitimate protest is that based on the fundamental objection to high-carbon bars. That, of course, is one on which there are always likely to be differences of opinion.

The Autoclave Test for Cement For somewhat more than a year the publicity given to the high-pressure steam or "autoclave" test for cement has caused considerable disturbance in the minds of many engineers as to the adequacy of the present standard specifications. The presentation of a paper on the subject before the American Society for Testing Materials at Atlantic City last week furnished occasion for a thorough discussion, so far as data are now available. Because of the importance of the subject and the agitation regarding it a large amount of space is devoted to it in this issue, beginning on page 13. The case is, decidedly, "not proven." Dr. Cushman well says in his discussion, "The question of the advisability of adopting this method as an acceleration test must depend principally upon whether or not it can be shown to be rational or to have any true bearing on the qualities of a cement which it is the intention to predetermine." The conclusions reached by Dr. Cushman and Mr. Wig are that the autoclave test, so far as their experimentation has shown, does not give reliable results. Moreover, the discussions of Messrs. Ferguson and Spackman indicate that in the tests made by the proponent of the autoclave methods those cements which failed under the autoclave show a higher strength in six months than those which passed the test. In other words, the very paper advocating the new test has internal evidence which indicates that the increase in strength in the autoclave has no relation to the strength in a structure. Moreover, the results obtained by the experimenters are exactly what were to be expected, for the Germans after an experience with the high-pressure steam test concluded many years ago that it was of no value. While, therefore, those participating in the discussion did not entirely condemn the test and indicated that they would pursue their studies farther, in order to determine its value, those who have been disturbed by recent agitation as to the adequacy of the present specifications may rest assured that the autoclave method has so far failed to demonstrate its value. There is nothing to prove that a cement bought under autoclave specifications is superior to one passing the standard specifications but failing under the autoclave test.

Reparation for Strike Losses A suit was filed against the Pennsylvania Railroad Company recently to recover losses sustained by shippers during the strike of freight handlers in New York a year ago. To speculate upon the possible outcome of the suit would be profitless here, but it is worth watching in view of the opportunity offered to find out who is to bear the collateral financial losses incident to labor disturbances. Of even more interest in this class of cases is the verdict lately rendered in favor of Wells, Fargo & Company in a suit against Jersey City for damages sustained by the company during an express drivers' strike. A jury awarded the company a verdict of $43,300 for damage to its property and loss of business, which they claimed was caused by the failure of the city to provide adequate police protection. Most states have statutes under which those whose property is destroyed by mobs may recover from the city or county in which the damage is done, and as it has been settled by the courts that business is property it is strange that more frequent efforts are not made to force municipalities to pay for the losses to businesses of all kinds rendered possible by failure during strikes to provide sufficient police protection for property and for those who wish to work. The Jersey City decision holds out an inviting promise of success in such suits, and also suggests to the layman that the shippers' suit first referred to may not lie against the railroad company or that the railroad may have a remedy, if anyone is to be mulcted, against the city that made an interruption of freight service impossible to avoid.

City Not Forced to Be Foolish An interesting decision has been rendered by the Supreme Court of Massachusetts in relation to the refusal of Commissioner of Public Works Rourke of Boston to expend some $300,000 appropriated two years ago by the city council for municipal gas-lighting equipment to be used in the illumination of minor streets, alleys and parks. It appears that at the time the order was passed the commissioner was investigating various systems of street lighting and came to the conclusion that it would be unwise for the city to make an outlay of this magnitude in view of offers by private gas and electric lighting companies to furnish the service upon acceptable terms. Upon the refusal of the commissioner to make the expenditure a member of the city council sought a writ of mandamus from the court to compel the carrying out of the order of appropriation. The court points out that the commissioner's belief that the public interests will be better served by making a contract with a private company makes it clear that the city ought not to be required to spend this large amount of money, for a purpose held by the commissioner to be unwise, unless absolutely compelled by some positive rule of law. No such compulsion is to be found in the city charter of Boston or in the general laws of the state, and the court holds that the appropriation of money for a specific purpose by the legislative department of the city does not make its expenditure mandatory on the executive officers in a case of this character. The decision clears the way toward the final negotiation of a contract with the Boston Consolidated Gas Company for the lighting of about 11,000 street lamps on a ten-year basis, unless the existing vigorous competition of the Boston Edison Company for this business becomes successful before the agreement is signed by the mayor.

Utility vs. Beauty Again The case of Utility vs. Beauty is an old one in the annals of architecture and engineering. It has again come up in the dispute over the plans for New York City's new $10,000,000 court house. The plans adopted for this structure, with the approval of distinguished authorities, provided for a circular building of the Coliseum order. It was hailed as a happy departure from the commonplace rectangle, and all was going well when the justices who are to occupy the building protested that while the beauty and grandeur of the proposed court house were undeniable, it would be extremely inconvenient, ill ventilated, badly lighted, that it would involve unreasonable expense, and that the building should be so constructed as to permit of extension to meet future needs without necessitating a construction beyond present requirements. The justices found almost every possible fault with a round court house except to declare it unconstitutional. And what makes it all the worse is that solely from the viewpoints of utility and economy the legal architectural critics seem to have good grounds for their criticisms. While agreeing to this, one cannot suppress the hope that a departure so promising as was made in the Lowell plans may be made to serve the demands of utility as well as satisfy the canons of beauty.

Winning Strikes "from Within" To talk too loudly of "sabotage" and advise workers to destroy the property of their employers may land in jail those who indulge in this variety of free speech. But to tell strikers to go back to work and "win their strike from within"—that is all right. The two things mean exactly the same thing, however, and it is strange that either should be for a moment tolerated. The four months' strike of the Paterson, N. J., silk workers is breaking up, but the desperate leaders of the Industrial Workers of the World are publicly advising their following to cripple machinery and damage products if they are compelled to go back to work. This is only a variation of the pleasant suggestion that sand in journal bearings or explosives in the coal bin are as good arguments as a stoppage of labor. The object is not merely to bring the employer to terms in a given dispute; the aim is to ruin him altogether. How this is going to benefit the employee has never been explained, but the mere statement that a large and growing body of workers had adopted sabotage as a policy should put employers—particularly those of unskilled labor, among whom the I. W. W. propaganda is rapidly growing—in an attitude of stronger defense than was ever necessary against any other labor movement. So far there is no evidence of concerted opposition among employers and on the part of the authorities to the I. W. W. movement. It has remained for the American Federation of Labor to voice the only condemnation the Engineering Record has heard of the Industrial Workers. Whether this condemnation springs from jealousy or better motives, it is voiced in language which shows an understanding of what it means when a labor movement runs mad. A similar understanding on the part of employers will save them a lot of trouble in the future.

The Meeting of the American Society for Testing Materials

The meeting of the American Society for Testing Materials at Atlantic City was generally conceded to be by far the best in the history of the organization. While some improvement is naturally expected from year to year as practice crystallizes into precedent, the very marked increase in the amount of business transacted and in the effectiveness of the discussion was due to the preprinting of papers. The broadening of activities, too, calling together the leaders in lines not hitherto pursued as actively as others by the society must also have been gratifying to the officers and members.

The amount of work accomplished is shown in the report of the meeting in the Current News Section of this issue. This included the consideration and passage to letter ballot of a large number of new specifications and modifications of existing ones. The committee on standard specifications for steel was especially active, presenting no less than nine new specifications and amendments to fourteen existing specifications. Among the new specifications presented by this committee was one for concrete reinforcement bars rerolled from old rail. Of particular interest among the papers were those on the autoclave test for cement, noted elsewhere in these pages, and on tests of large reinforced-concrete slabs by the Office of Public Roads.

The preprinting of papers and their advance distribution, which were generally commented upon at the meeting, are particularly important with respect to committee reports, proposed specifications and modifications of existing specifications. When specifications are read from manuscript there is no time for that careful deliberation which is necessary for the intelligent criticism of technical matters. In the past much of the discussion of reports and specifications, therefore, was rambling, much time was lost and members who might otherwise have contributed valuable data were prevented from so doing. Under the new plan, however, there was ample time for advance consideration and the discussions were consequently brief and to the point.

In the presentation of papers, moreover, there was great economy of time, all the speakers coming well within the ten-minute limit set for the presentation of summaries. Generally, too, the members discussing papers were well prepared and did not exceed the five-minute limit.

The method of distributing the papers at the meeting is also deserving of note. On registering, each member and guest received a full set of the preprinted reports and papers, the group of papers for each session being inclosed in a separate envelope, with the number of the session printed thereon.

The sessions dealing with steel and concrete drew the largest attendance, but the interest in the sessions at which brick, lime, waterproofing and road materials were discussed indicates that if the great amount of work heretofore done on the steel specifications will now have a tendency to diminish there are fields comparatively untouched in these other lines that will for years engage the best endeavors of the members of the society. Not only was the interest in these subjects keen, but among those in attendance were acknowledged authorities in the several lines.

Railroad Construction and the Canadian West

The present financial status of Canada has received considerable attention of late, and more than one American writer, in endeavoring to show how conditions in the United States are affected by Canadian affairs, has pointed out that Canada has been borrowing sums which are out of proportion to the value of the exports she is making. This has a close relation to engineering—is, in fact, engineering in the broadest sense—because the extensive borrowings are almost wholly for development work. It should be remembered that Canada's position is unique in the matter of development. Conditions in her western provinces make for a rate of progress, especially in railroad construction, which is so rapid that it is not feasible to expect trade and manufacturing industries to keep pace. The railroad companies have been quick to appreciate the value of getting rails laid early in new territory, opposition lines often racing to be first to tap a choice district. Thus a great amount of new mileage has been laid out, and there is no doubt that British Columbia, for example, will see more miles of railroad constructed within the next few years than any like area on the continent. It is reported that this year the budgets of three railroads totaled $135,000,000 for work in British Columbia alone, and at the present time an army of more than 15,000 men is engaged there in railroad construction. With a population averaging about one resident per square mile it is absurd to expect British Columbia to produce, for some time to come, an increase of exports proportionate to this enormous development.

Some economists have asserted that this "overdevelopment" will work out more to the disadvantage of the new territory than if development had been checked to await industrial progress; but it seems doubtful if any argument can show, in ultimate analysis, that it is wise to discourage the legitimate opening up of new territory when capital is available for the work. Finally, it may be observed that extensive loans are not made without a knowledge of conditions, and it is fair to suppose that those who control the capital which is now developing western Canada have assured themselves of security and returns. It is a significant fact that in a report of the Canadian Conservation Commission, published as late as 1911, it is stated that fully 95 per cent of the water powers of British Columbia were either unknown or had not been gaged. In a territory abounding in raw material and newly supplied with transportation facilities the capital invested in railroad development, according to President Shaughnessy of the Canadian Pacific, is "building up assets very much more valuable than the actual cash invested in them."

A Step in Advance by the American Waterworks Association

The conclusion to sectionalize the American Waterworks Association was the most important business transacted by that organization at its Minneapolis convention last week. The membership has grown so large and the papers so numerous that it has become essential to subdivide the work.

Many valuable technical papers have been given to half-awake audiences because the subject was not interesting to all. Managers and the higher officers hang on every word of such an excellent paper as that of Mr. Halford Erickson, of the Wisconsin Railroad Commission, on "Rates and Rate Making," but the young bacteriologist is likely to "cut" this session. Likewise the highly specialized subject, whether gelatin or agar media should be adopted as a standard, could hardly be expected to hold the attention of the accountants. There are general subjects, of course, in which everyone has an interest. The small-town manager, who must be an expert on chlorine treatment as well as on pipe-laying and rate-making, may still reap the advantages derived from a broad consideration of waterworks problems by attending the special sections in which matters that interest him are to be discussed.

To meet the demand for local co-operation in handling local problems state and section societies composed of men interested in waterworks have been formed. It is hoped that those organizations already in existence will affiliate with the national association and that further sections will be formed. There should be 5000 members in the parent society and the idea of holding meetings locally will go far toward bringing many into the association who can rarely attend any but local meetings. Whether or not all of the local societies will agree to the conditions in the new constitution remains to be seen. Already a section for analysts has been formed, and the members from Iowa are planning to organize a state branch.

An attempt will be made next year to revivify and popularize the question box and the experience meeting by devoting an entire day to questions of interest to the superintendent from the small city. It is felt that the "little fellow" needs more help and assistance than he has been getting. Discussions in these meetings for the past two years, although attended by a mere handful, have been extremely spirited and profitable. In consequence the day of the largest attendance has been chosen and numerous "short-story" experiences are solicited. The Engineering Record hopes that this feature may be carried out successfully because in the past many have felt that the greatest good from attending the meetings was obtained through private discussions with other members. The question box and the experience meeting amplify this individual contact. Descriptions of successful installations are valuable, but for the man running a plant they are not nearly as valuable as frank confession and discussion of difficulties. By planning the meetings in advance and sending out circulars suggesting topics for discussion much can be done to increase the value of these sessions.

The Denver Water Case

The recent decision of the United States Supreme Court in the litigation between the city of Denver and the Denver Union Water Company brings a long and bitterly contested controversy to a conclusion. The result is a sweeping and definite victory for the city in its efforts to secure municipal ownership of its water supply.

The decision, probably as completely surprising to the city's representatives as it must be gravely disappointing to the company, is based upon grounds of the utmost simplicity. It has interest to the engineer as an indication of the present trend of legal opinion, influenced by public agitation, and of the increasing responsibility devolving upon professional men advising municipalities under these changed conditions.

The Denver Union Water Company succeeded to a franchise granted by the city of Denver to the Denver Water Company, by an ordinance of April 20, 1890. One section of that ordinance provided that "at the expiration of the period of twenty years from and after" its date, "in case the city shall then elect so to do, . . . the said works may be purchased by the said city," and the methods of determining the fair cash value of the property were arranged. It was stipulated that the decision of a majority of a board of five appraisers should be final and binding upon both parties, and that upon the tender of payment of the award by the city to the company the latter should convey to the city all of its property and "thereafter, all franchises, rights and privileges shall cease and be at an end."

The following section provided that, at the expiration of the same period, "the city may, at its election, renew the contract" for another period of twenty years, with a reduction of hydrant rentals.

In October, 1907, the city adopted an ordinance, accepted by the company, providing for the appraisement of the plant by a board of five appraisers, who were also to establish a schedule of rates for the ensuing twenty years, and, generally, for carrying out the provisions of the ordinance of 1890, anticipating its termination. This later ordinance provided that if the electors should refuse to accept either proposition at that time there was no waiver of either party of its rights under the contract of 1890.

The appraisal board, consisting of Messrs. F. P. Stearns and M. L. Holman for the city, Mr. J. R. Freeman and the late C. L. Harrison for the company, with Mr. Allen Hazen the fifth member, by majority fixed, as of March 20, 1909, the fair value of the plant at $14,400,000, Mr. Stearns assenting to all parts of the report except the valuation of the water rights. The board failed, however, to fix a schedule of rates.

By their actions up to that time both parties to the original contract plainly acted upon the assumption that the city was under obligation in 1910 either to purchase the plant at the valuation set by the board or to renew the franchise. The city manifested that belief by passing the ordinance of 1907; the water company did so not only by accepting that later ordinance but by proceeding, during the life of the contract, to extend and improve the plant.

At an election on May 17, 1910, three propositions were submitted to the electors: (a) To vote $17,000,000 for the purchase of the company's property and for necessary extensions and enlargements; (b) to grant the company a new franchise for a period of 20 years on a different schedule of rates, and (c) an amendment to the charter creating a Public Utilities Commission, and investing it with large powers as to construction, acquisition, maintenance and operation of a water plant. This amendment declared against the exercise of any option to purchase or renew any contract with reference to a water plant, except upon a vote of the taxpaying electors, and authorized the issuance of $8,000,000 in bonds to provide a municipal water plant. Of that amount $7,000,000 was to be paid for the existing plant, if accepted by the company within a certain time, and the remainder to be used in repairs and similar work; or failing the company's acceptance, the whole sum, subject to ratification at a later election, was to be devoted to the construction of an independent municipal water plant.

The first and second proposals were overwhelmingly defeated; the third was carried by a small majority of an insignificant portion of the qualified taxpaying electors.

Since that time the Denver Union Water Company has spent about $2,000,000 in extensions and betterments to the plant—convincing evidence of its belief that the city had still to comply with the terms of the ordinance of 1890.

The U. S. Supreme Court has now declared that, under the terms of the contract of 1890, the city of Denver could either purchase the plant or renew the franchise, but was under no obligation to do the one or the other, that the adoption of the charter amendment at the election of May 20, 1910, contemplating a purchase not in the terms of the option conveyed in the ordinance of 1890, was a rejection of that option, and that the declaration to acquire independently either by offer to purchase on its own terms, subsequently declined, or by construction of a new plant was an action entirely within its rights. In brief, the Denver Union Water Company is left as "the undoubted owner of the physical property constituting its plant, without a franchise to maintain and operate it through the streets of the city, the prior franchise having expired."

The importance of the recent decision extends into the future, in the responsibility now attaching to the city, and especially to its Public Utilities Commission, in the performance of its duty to the taxpaying citizens. The city has been advised that an adequate water supply can be constructed for a population of 500,000 inhabitants at a cost of less than $8,000,000.

The Public Utilities Commission is now charged with the responsible task of constructing a plant at that cost, in face of the appraisal of the company's properties at $14,400,000 by the board of five. The alternative proposition of offering to purchase the existing plant for $7,000,000 is not now available; the offer has already been made and declined.

In the present temper of the public toward efficient administration of municipal works, the commission would not have a pleasant time if it commenced the construction of an independent plant with that bond issue as a foundation in the hope that additional money would be forthcoming when required. It, doubtless, would be, but it would be accompanied with the condemnation of the professional advisers who misled the taxpayers originally.

And, in the present financial and industrial condition of Denver, seeking and requiring the aid of outside capital for the development of its resources, the wisdom of utterly destroying the value of an existing water plant, built up by the energy and capital of its own people, may well be pondered, even if the highest court of the land has declared that "the city is free to name its own terms and the water company is likewise free to accept or reject them."

The Public Utilities Commission of Denver, and its professional advisers, have a task to perform calling for the unusual exercise of judgment and good sense in following up the victory won before the Supreme Court.

Incandescent Lamp Improvements

Among the engineering subjects discussed at the recent Chicago convention of the National Electric Light Association none was of greater interest than the improvements of the past year in the design and manufacture of incandescent lamps. The efficiency of the wire-type tungsten lamp is now practically 1 watt per candlepower, and recent researches have borne good fruit in preventing deposits on the glass which formerly made it necessary to throw lamps away long before filament breakages occurred. Striking developments within the last few months in the use of helical filaments have also brought about the introduction of the so-called "focus" type of lamp, which seems destined to supersede the rather complex and often troublesome projector arc lamp except where extremely powerful effects are necessary. These gains mean much in money to the consumer of current, and they are also advantageous to the central-station industry through the inducement which they offer to make greater use of the service. The gain in filament efficiency, to be sure, is but 0.15 watt per candlepower for the year, but it means a perceptible saving on every good-sized installation, while the extension of the working life of the lamp is a real gain from the maintenance standpoint.

One of the most important advances, however, which have ever been accomplished on the engineering side of illumination is the increased accuracy with which tungsten lamps are now rated for either current or voltage requirements. The inability of the manufacturers to produce carbon or metallized filament lamps good for an exact predetermined circuit led in the past to a multiplication of distributing apparatus extending roughly from about 104 volts minimum to 120 or 125 volts maximum. Under these conditions a lamp which operated satisfactorily on one circuit when transferred to another city soon burned out on account of excess voltage or else yielded far less than its normal light output. These departures from a standard voltage involved the manufacturers in great but apparently necessary complications in design and necessitated the tying up of capital in equipment which could not be interchanged with good results. In the street-lighting field small differences in lamp rating necessitated correspondingly large expenditures for specialized apparatus and made diversified systems take the natural place of unified ones.

The extreme precision with which lamps can now be manufactured for stated circuit requirements largely does away with these drawbacks and insures a standardization which augurs well for lower costs. It is difficult to forecast at this time how far the movement toward the standardization of distributing systems will be carried, but as such systems are coalesced into networks and as new ones are built, accurate lamp production is certain to be most valuable, for a uniform voltage means economy all along the line.

Closure of Beulah Levee Crevasse

Emergency Repair Work in the Lower Mississippi River Valley

By A. L. Dabney, Chief Engineer, Dabney Engineering Company, of Memphis

The successful closure of the Beulah levee crevasse, Bolivar County, Mississippi, marks a new era in the handling of such situations on the Mississippi River. The method used was generally the same as that employed by Mr. H. T. Corey in closing the Colorado crevasse, but was successfully applied on the Mississippi River for the first time at Beulah.

The closure of a crevasse in a Mississippi levee while water ran through it has been of exceedingly rare occurrence. In most cases the inaccessibility of location makes it impracticable to use steam equipment, and the only accessible earth is in the small part of the levee that is above water, with no rock available. The experience has usually been that by the time equipment, materials and forces can be assembled and work got well under way the flood has wellnigh subsided.

SITUATION AT BEULAH

Conditions at Beulah were peculiarly unfortunate. The levee gave way in April, 1912, forming a crevasse 3400 ft. wide in a levee 23 ft. high. A large territory, about 2100 sq. miles, was submerged until late in the planting season, and the resulting money loss to planters, towns, mills and railroads was very great. By a combination of unfortunate circumstances an unusually early rise of the river in January, 1913, found an open gap in the new levee which was then under construction around the crevasse. A large part of the district, struggling to recover from the inundation which it had suffered but nine months before, was again flooded.

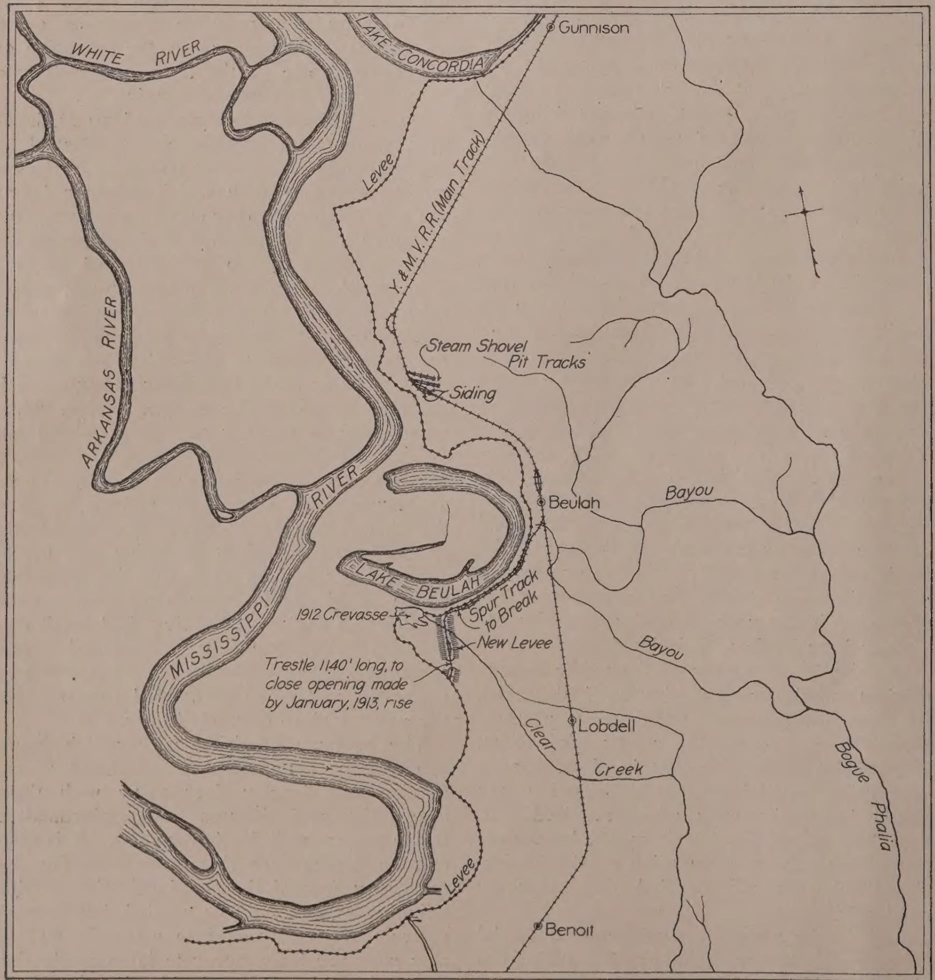
There remained three months or more of the usual flood season, when a second rise might reasonably be expected, subjecting this area to a third overflow within twelve months. It was imperative to close the gap, if possible, before another rise could come. Heroic measures were adopted, and that the feat of closing and holding this break was accomplished is greatly to the credit of the Mississippi River Commission, the engineers in charge, and the superintendent of the work.

The map and cross-sections show the situation at Beulah and the size of the levee that broke on April 17, 1912. The water, still rising, had just reached the top of the levee, and was about to go above the levee proper and against the sandbag topping that had been placed. For many miles the levee line was under very nearly all the stress it could stand, and it was almost inevitable that a break should soon occur in that section of the river.

THE BREAK IN 1912

The manner in which this break occurred is described as follows by Mr. W. J. Shackleford, chief engineer, Lower Yazoo Levee District, in his published report of July 8, 1912:

"On April 12 the Arkansas levee broke at Panther Forest, which is 47 miles by river below Beulah crevasse and about 29 miles above Greenville. This break afforded relief to our leeves as far up as Catfish Point, but above there the water continued to rise until April 17, when the levee gave way near the foot of Lake Beulah, just below Prentiss crossing, at about Station 2105 to 2108. The levee at the particular point where it broke had given no previous trouble. It was topped with sacks, but the water had hardly reached the sacks at that point. The crown was only 4 ft. wide for about ½ mile each side of the break, this topping having been put on in 1906 to a grade of 3 ft. above the 1903 water level. There was a break immediately in front of this one in 1882, and the levee was rebuilt close to the blue hole and probably over some of the sand thrown out by the break. It was composed largely of poor sandy material, and the foundation was of the same character. All Lake Vermillion, Neblett, Buck Ridge and Eutaw levees just below this break were in a very precarious condition and liable to go at any moment.



Plan of the Beulah Levee District, Showing Location of Crevasses

"Mr. W. L. Withers was in immediate charge of the work in the vicinity of the break, under Mr. L. Lowrance; he had a camp with about forty men, with plenty of materials, a short distance from the break.

"The break occurred about nine o'clock at night. There were hundreds of boils below this place, and all that looked at all serious were being promptly worked on. This one was noticed about 4 p. m., and at 6.30, Mr. Withers states, it did not look serious, but he decided to 'hoop' it anyway. After he started work it began to look alarming, and he sent for additional forces. The convicts were at the Clark place a short distance above and did not get half way before they were met by the water, so sudden was the break. All the camp outfit of Mr. Withers was lost before they could get to it; also, the convict camp.

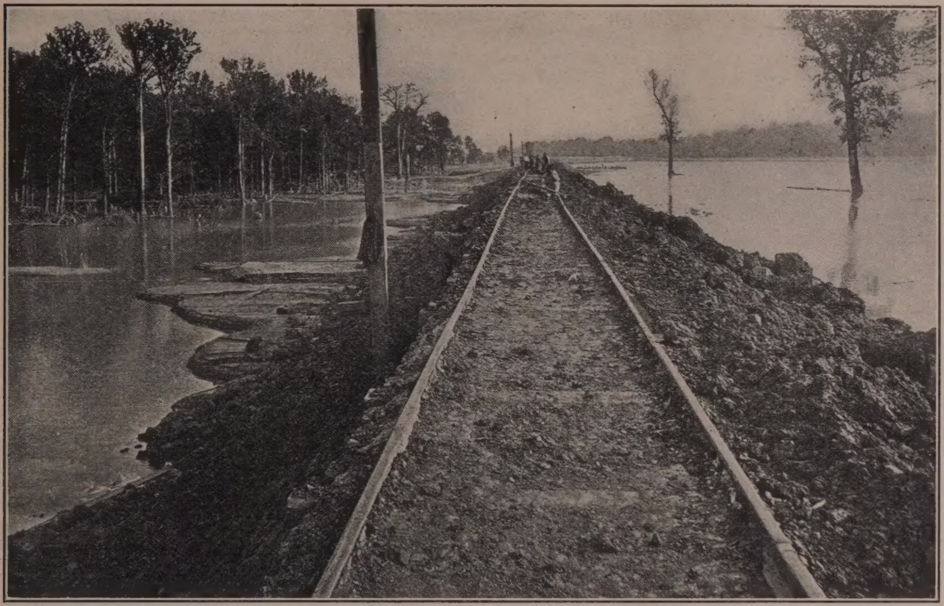
"Both Mr. Withers and Mr. Lowrance are experienced in high-water work, Mr. Withers having been on the levee in nearly every water since 1891. Mr. Lowrance is a levee contractor of the highest standing and ability, and I am sure that both he and Mr. Withers did all that men could do to hold the levee intact.'"

Mr. Shackleford further states that the crevasse overflowed 2723 sq. miles, including about 600 sq. miles already covered by backwater, coming up the Yazoo River from its mouth.

Mr. Shackleford appends a letter from Mr. Withers, which is, in substance, as follows: At 6:30 p. m. the guard reported to Mr. Withers at his camp a newly developed "sand-boil." At 7.05 p. m. Mr. Withers began building a "hoop" of sandbags around the boil to pond water over it. This sand-boil, located at the base of the banquette at *A* in the cross-section of the levee, at the first break had not discharged more than a barrelful of sand; but about the time work was started on it another boil appeared about the middle of the banquette at *B* and bubbled all around within a radius of 15 to 20 ft. There was another boil about 150 ft. landward from point *A* in the borrow pit. Mr. Withers continues: "Had there been five hundred men there I don't think I could have prevented this break."

As stated, the water from this crevasse submerged about 2100 sq. miles. About one-fourth of this area is in cultivation. It cut off train service on the three branches of the Yazoo & Mississippi Valley Railroad between Vicksburg and points north, and on several minor branches of that road and also on the Southern Railway from Greenville east. The water ran off so that planting operations and train service could be resumed about the latter part of May.

After the 1912 flood subsided Congress



View Along Portions of Repaired Levee, Showing Character of Material

appropriated $1,500,000 to be used by the Mississippi River Commission in closing the crevasses on both sides of the river. The U. S. engineer officer at Vicksburg promptly advertised for bids to build new levees around the several crevasses in his district. On the Beulah levee, as on others, the bids all exceeded the allotment. These bids were rejected and the work readvertised.

The Sequence of Events

The second set of bids was received in the latter part of July, and all were again in excess of the allotment. The local levee board then agreed to pay the difference between the amount available to the U. S. engineer and the lowest bids, and the work was awarded.

The estimated quantity in Beulah levee was 690,000 cu. yd. The prices ranged, on the several contracts into which it was divided, from 33 and 34 cents a yard to 42 cents on the lowest section, which looked formidable for team work; it was "buckshot" soil, very low and wet ground, and involved a long haul and in heavy timber. The U. S. engineer contracted to pay 30 cents per yard and the levee board was to pay the balance.

At the first advertising the date for completion was set as Nov. 30, but upon readvertising Jan. 31, 1913, was set for completion, in the hope of getting materially lower prices than were expected if the time were made shorter. Occasions have been rare when the river has come so high in January that levee work could not be continued behind a small temporary "protection levee."

Work was begun in August and fair progress was made during the early fall. The months of December and January, however, were practically the worst of record. There were only about ten fair working days in December and none in January. An unusually high water for that month came in January. A protection levee was built round the 1912 crevasse in the old levee to an elevation equivalent to 40 on the Arkansas City gage. On Jan. 18 the water came over this protection levee and against the new levee.

When the January rise appeared in the upper rivers, state convicts were rushed to Beulah, and a 100-ft. gap in the new levee that had not been reached by the team force was closed by a bank about 20 ft. high, of sand-filled bags, built in the face of the rising river. Two such bag levees were built behind the first to step down the head of water. On Jan. 25 this sandbag structure, under a total head of about 15 ft., suddenly began to sink, causing the breach of the front dike. The rush of water quickly swept away the second and third dikes, and for four weeks the water again flowed over the country behind, and again interrupted train service.

The profile of the new levee shows the gap of 1100 ft. that was washed in the new embankment as the water rushed through.

Throughout the fall, when it would have been possible to push the work more vigorously, neither engineers nor contractors suspected that the last two months of the contract time would be a continued spell of such wet weather as to make team work practically impossible and that January would bring a flood of very unusual stage for that early season. Had either contingency come without the other, the embankment would have been finished before the April rise.

The Yazoo & Mississippi Valley Railroad had been a heavy sufferer from the two floods, and would be from a third. This road has a main line 2½ miles east of the new crevasse, over which passenger trains between Memphis and Vicksburg are run. There is another main line about 15 miles further east, over which through trains run to Vicksburg and New Orleans, and a branch between the two, besides other branches, in the path of the water from the break. It was of special interest to the railroad to prevent another flood from going through.

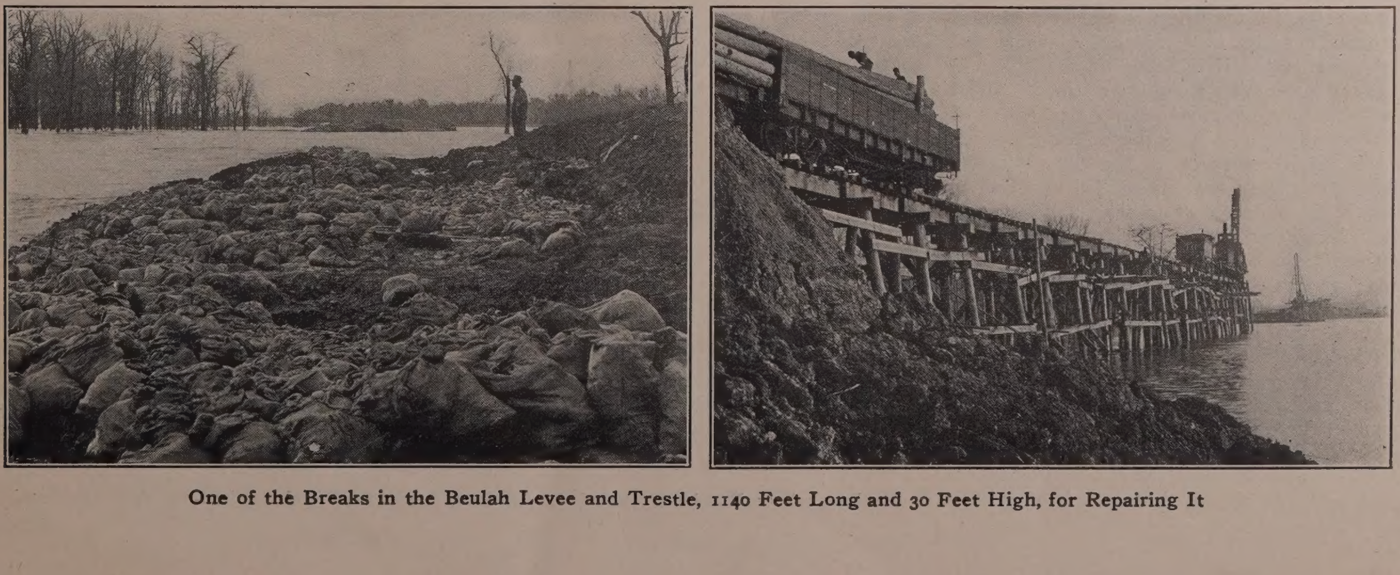
On the evening of Feb. 6 the terms of a contract, by authority of the Mississippi River Commission, was agreed upon between the U. S. engineer officer and the railroad's representatives, providing that the railroad company, as agents for the U. S. Government, should close the crevasse. The railroad was to be paid the cost of all labor and materials, plus a percentage to cover overhead charges. At this time there was still a large volume of water flowing through the break.

Brief History of Operations

Mr. T. L. Dubbs, superintendent of the Vicksburg Division, Yazoo & Mississippi Valley Railroad, took personal charge for the railroad company. On Feb. 7 he had materials and equipment moving toward the break. On Feb. 8 track-laying was begun on the spur track running from the main line of the railroad near Beulah station to the break.

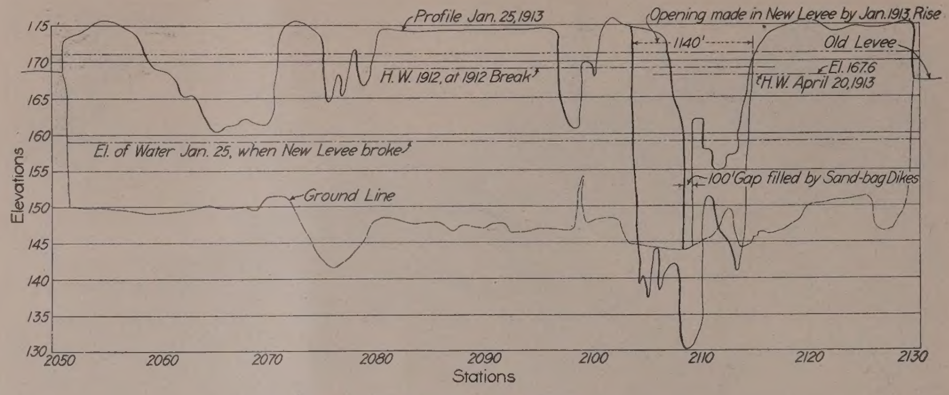
During the first three days of track-laying it rained constantly. During the remaining days it was very wet. The men worked in mud and water a foot or more in depth, laying the track across the cotton field between the railroad and the levee, a distance of 2200 ft. From where the spur track reaches the levee it was built on the banquette, which was rounded up with road graders in advance of track-laying. On most of the line the ties were laid on "slabs."'

Ties were loaded on barges at Rosedale, floated down beside the levee, and laid in place on the banquette by Mr. Lilly, U. S. junior engineer, with a force of government laborers, in advance of the steel gang.



One of the Breaks in the Beulah Levee and Trestle, 1140 Feet Long and 30 Feet High, for Repairing It

On Feb. 16, eight days after track-laying was begun and ten days after the work was decided upon, the 4.3 miles of track to the north end of the break had been completed. The track was ballasted with cinders. On Feb. 17 pile-driving was begun with a track pile driver at the north end of the break. Meanwhile a creeping pile driver with piling and bridge materials had been floated on barges to the south side of the break by the government forces, and driving from that end was begun on Feb. 20.



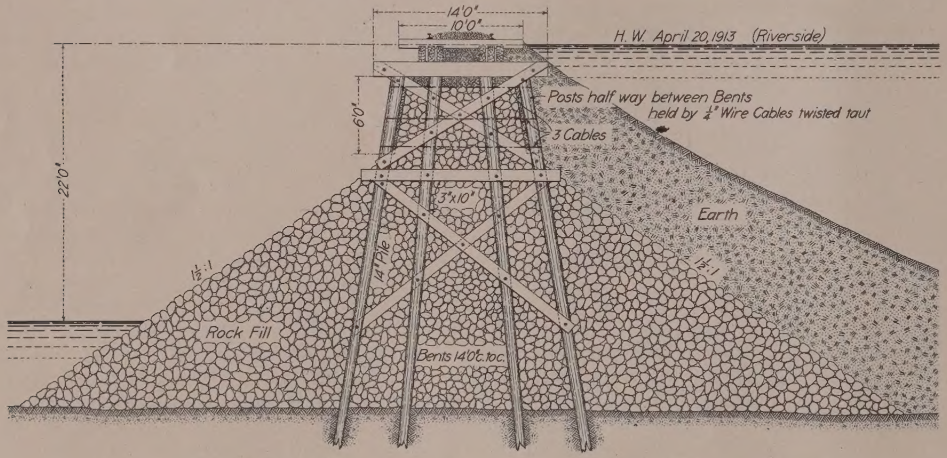
Levee Profile at Time of Break, Jan. 25, 1913

The swift current running through the break for several weeks had washed away all soft material in the surface strata, and left a hard, stiff "gumbo" or "buckshot" bottom. The average length of piles was 65 ft.; average penetration, 20 ft.; highest bent, 45 ft. from rail to ground; average height of trestles, about 30 ft. Untreated pine piling was used.

Pile Driving

Eighty-three bents were driven, a few having five piles each, the others four piles. The length of the trestle is 1140 ft. The pile drivers worked day and night and the trestle was completed March 3, twenty-five days after the contract was made and twelve days after the track reached the break.

When the first piles were driven some difficulty was experienced because of the swift current, running at a depth of 16 to 25 ft. Several piles, being swept against the pile driver leads before striking bottom, were broken off at the bottom of the leads and tumbled end over end down the current. The water was falling, however, and the pile driving was completed in dead water an average of 16 ft. deep.


14'0"
10'0"
H.W. April 20,1913 (Riverside)
6'0"
22'0"
Posts half way between Bents held by ¼" Wire Cables twisted taut
3 Cables
3"x10"
Earth
1½:1
14' Pile
Rock Fill
Bents 14'0" c. to c.
1½:1

Details of Trestle and Embankment Repair Work

A number of cars of rock had been contracted for by the U. S. engineers, shipped in from quarries in Kentucky, Alabama and Arkansas, and were standing on available sidings for many miles along the railroad. About half the cars contained riprap size and half of them quarry run, some pieces being so large as to require shooting in the car to unload them. The large quantity needed in a limited time made it necessary to take any size that could be had promptly. Rock was handled in various types of cars, about half being bottom-dump cars. The top of the trestle was built open so that the cars could be dumped.

On March 3, the day that the trestle was finished, the unloading of rock at the trestle was begun and carried on by the combined labor forces of the railroad and the government. The last of the 1402 cars, holding about 50,000 yd. of rock, was dumped about April 2, and the rock was then topped off even with the ties, with 1000 yd. of gravel. This gravel surface proved invaluable, as the very stiff, mucky buckshot dirt could be cleaned off its surface with a facility that would not have been possible on the exposed rockfill. The gravel also gave firmness to the surface.

The required quantity of rock was ordered on the basis of 1 to 1 slopes. Instead, the rockfill assumed about 1½ to 1 slopes; and to make the available supply reach up to the track, the top 6 ft. of the bents, below the caps, were boxed in as shown in one of the drawings. The plank walls of this box were tied together midway between bents by three ¼-in. wire cables doubled, passing around 6 x 10-in. verticals outside of plank and twisted taut.

Cutting Off the Flow

The second 1913 rise came through the old crevasse and against the new levee and rockfill on March 27, before the rock was all in place. Flow through the rockfill was free, at a moderate velocity, not sufficient to further erode the buckshot bottom. As the water continued to rise the flow increased, but the natural drainage channels accommodated most of the water that flowed inland from the crevasse, so that comparatively little low land and no cultivated lands of any consequence were submerged. Mr. Dubbs estimated that before any earth was dumped over the rockfill 1½ per cent as much water passed through as would have gone through the gap if entirely open.

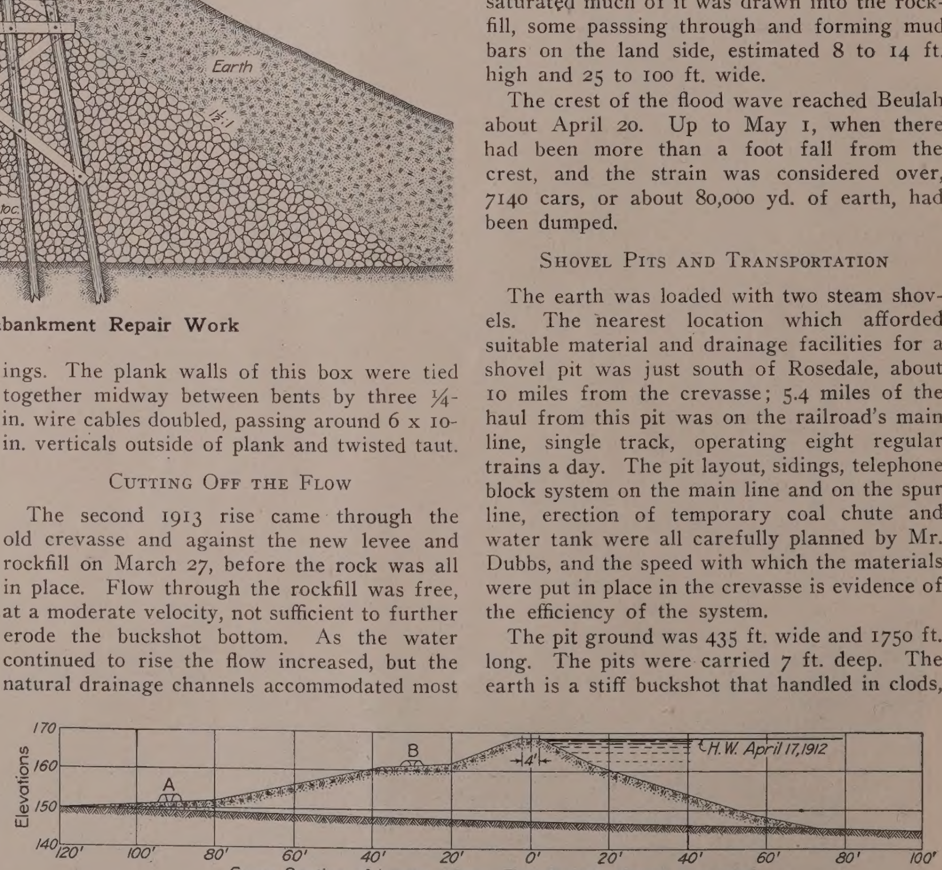
On April 3 the first earth was dumped on the river side of the trestle, and from that time earth was hauled in and dumped constantly throughout the rise and fall of the flood. From the time that the dumping of earth was begun the water on the land side of the fill began to recede, very slowly at first. By about April 14 the flow through the rockfill was practically stopped and the low lands were relieved of water. As the earth became saturated much of it was drawn into the rockfill, some passsing through and forming mud bars on the land side, estimated 8 to 14 ft. high and 25 to 100 ft. wide.

The crest of the flood wave reached Beulah about April 20. Up to May 1, when there had been more than a foot fall from the crest, and the strain was considered over, 7140 cars, or about 80,000 yd. of earth, had been dumped.

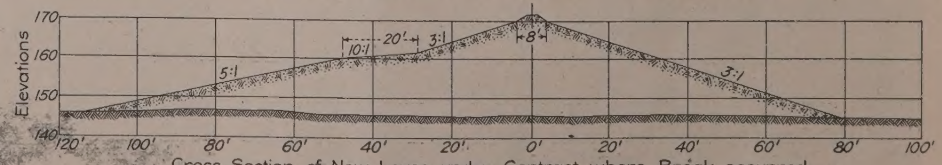
Shovel Pits and Transportation

The earth was loaded with two steam shovels. The nearest location which afforded suitable material and drainage facilities for a shovel pit was just south of Rosedale, about 10 miles from the crevasse; 5.4 miles of the haul from this pit was on the railroad's main line, single track, operating eight regular trains a day. The pit layout, sidings, telephone block system on the main line and on the spur line, erection of temporary coal chute and water tank were all carefully planned by Mr. Dubbs, and the speed with which the materials were put in place in the crevasse is evidence of the efficiency of the system.

The pit ground was 435 ft. wide and 1750 ft. long. The pits were carried 7 ft. deep. The earth is a stiff buckshot that handled in clods,



Cross Section of Levee where First Beulah Break occurred



Cross Section of New Levee under Contract where Break occurred

Sections where Breaks Occurred on April 17, 1912 (Top) and on Jan. 25, 1913 (Bottom)

frequently nearly the size of the shovel. This was a great advantage, because these large clods rolled directly to the toe of the slope; otherwise percolation might have been checked elsewhere before it was at the bottom, thus inviting undermining of the fill.

The shovels were 65-ton Atlantic type. The cars used for earth were Haskell-Barker standard side-dump ballast cars. Full trains carried twenty cars. After the banquette became soft from seepage trains carried ten to fifteen cars. Earth was unloaded on the water side by side plows and Lidgerwood unloaders.

Steam shovels and trains were operated twenty-four hours a day. Marine lights and Melbourne acetylene gas lights were used.

All trains, including the regular trains on the main line and the material trains on the spur, were handled by the telephone manual block system. There were four block stations with telephone houses and sidings on the main line and three on the spur line. Train movements were controlled by train directors stationed at the steam shovel yard, with block-signal men at the block stations twenty-four hours per day.

Comments on the 1913 Flood

The results of the 1913 flood argue most favorably for the ultimate complete success of the Mississippi levee system. In the lower St. Francis district, pronounced by its chief engineer before the 1912 water as only 60 per cent complete (and not enlarged since), only three breaks occurred in a frontage of 215 miles, and only 50 per cent of this district was flooded. The only break on the east side of the river from Cairo to the Gulf was such a short distance above the mouth of the Yazoo River as to flood little land not already covered by backwater.

From New Madrid, Mo., to within 40 miles of Memphis the levee west of the river, though very inadequate in size, was held intact. The levee from Helena, Ark., for 60 miles, by river, southward was held, although for 20 miles of this levee the water was above its top—in some parts as much as 2 ft.—restrained by temporary topping. From the mouth of Arkansas River to the Gulf there was only one break on the west side of the river. Of 14,000 sq. miles of land under levees in Louisiana only about 3 per cent was submerged.

In 1913 the river was about 1 ft. higher than during 1912 at Cairo, Memphis and Helena, and was higher for some distance below Helena. At Arkansas City it was 0.3 ft. lower; at Vicksburg, 0.5 ft. higher in 1913.

The difference resulted from the anticipation of a big water by the levee people early enough to make extensive preparations.

The work of building the new levee and closing the 1913 crevasse was under the Mississippi River Commisssion, in charge of Major J. A. Woodruff, Corps of Engineers, U. S. Army. Mr. E. C. Tollinger, U. S. assistant engineer, has general charge of the levees on the east side of the river in the Third district. Mr. Arthur Hider, U. S. assistant engineer, was in general direction and Mr. A. Miller Todd, U. S. assistant engineer, in local charge of the closure of the crevasse, being assisted by Mr. R. C. Lilly, U. S. junior engineer.

Mr. W. J. Shackleford is chief engineer and Mr. Robert Somerville assistant chief engineer of the Lower Yazoo Levee District, in which Beulah is located.

To the above-named gentlemen and to Mr. T. L. Dubbs, superintendent of the Yazoo & Mississippi Valley Railroad, the writer is indebted for the information contained in this paper.

Mechanical Filtration Plant at Clarksburg

Details of Design, Results of Operation and Cost of Filtered Water

By H. W. Streeter, Formerly Chemist in Charge

The mechanical filtration plant at Clarksburg, W. Va., is part of a comprehensive plan of water and sewage improvements carried out through the progressiveness of the local waterworks and sewerage board, under the general direction of Messrs. Hering & Fuller during the years 1910 and 1911. It is of modern reinforced-concrete design throughout, with a present rated capacity of 3,000,000 gal. per day. Provision was made in the design for convenient extension to its ultimate capacity of 6,000,000 gal. daily.

Water is taken from the west fork of the Monongahela River at a point about 1 mile south of the city by two low-lift Worthington centrifugal pumps of 3,000,000 gal. per day capacity each, driven by A. B. C. engines and pumped to the coagulating basin, located near the plant just back from the river. After passing through this basin the water flows by gravity to the headhouse containing the filters and appurtenances. The effluent from the filters drops through trapped effluent pipes into a 200,000-gal. filtered water chamber extending under the headhouse below the ground level, whence it is pumped to a reinforced-concrete standpipe of 1,000,000 gal. capacity, located at such an elevation that a pressure of about 105 lb. is maintained in the business section of the city by gravity flow.

The coagulating basin is constructed of reinforced concrete and has a total capacity of 600,000 gal. It is divided into two duplicate sections, with connections so arranged that they may be operated together or separately, in series or in parallel. Each section is divided in the direction of the flow by one long vertical baffle. The bays are drained by 12-in. sludge trenches, sloping toward 8-in. sluice gates opening into 8-in. leaders which connect with a 10-in. drain. Stability for side walls of the basin under load is obtained by the use of tie beams at the top and bottom. These walls thus act as vertical beams.

Filters

The four filter tanks are of reinforced concrete, 8 ft. deep, and have a combined sand area of 900 sq. ft. All valves connected with the filters are operated hydraulically from tables at each filter, the power being taken from the high-pressure filtered water main. The sand, 27 in. in depth, has an effective size of 0.40 mm. It is underlaid with 9 in. of graded beach gravel. The strainer system is of standard Jewell design. The rate controllers, one for each filter, are of the Simplex closed type, operating through a total available head of 12 ft.

For washing the filters air and water are supplied through the same manifold system separately by a Roots blower of 900 cu. ft. per minute capacity and an 8-in. Worthington centrifugal pump. Both are driven by 24-in. Pelton water motors, direct connected, which derive power from the high-pressure water main and exhaust into the filtered water basin. The wash-water troughs are of cast iron, four to each filter tank, and their tops are located 13 in. above the sand level.

Chemical Feed System

The chemical feed system provides for the application of aluminum or iron sulphate, lime and hypochlorite. Solution tanks, feed lines, orifice boxes, solution pumps and connections are in duplicate and cross-connected throughout, insuring continuous service and maximum flexibility of application. The coagulant may be applied at two points separately or simultaneously.

The alum and hypochlorite tanks, of 3000 and 500 gal. capacity each, are of concrete, and the lime tanks, 1500 gal. each, are of ¼-in. wrought iron. The alum tanks are provided with dissolving boxes of 800 lb. capacity each and with spray pipes for the slow dissolving of salt when making up solutions. Over the hypochlorite tanks is set a heavy cast-iron digester, with overflow connections into each tank. Provision is made for heating the water supply to the lime tanks with live steam. All tanks are provided with mechanical agitators, float gages reading in gallons, and Acton valves for automatically cutting off the water supply when tank is filled.

Machinery

Below the solution tanks, on the ground floor, are located the solution measuring boxes and pumps. The solutions flow by gravity into the orifice boxes and, after being measured by hard-rubber annular orifices adjustable in size of opening by micrometer settings, are pumped against head of water in the coagulating basin from suction boxes. The orifice boxes operate under a constant head. The solution pumps are of phosphor bronze and are guaranteed to withstand the corrosive effects of solutions not exceeding 4 per cent in strength. They are driven from a line shaft by 12-in. Pelton water motors.

The machinery room and pipe gallery are located on the ground floor of the headhouse, directly over the filtered-water basin. Upstairs, over the pipe gallery, is located the operating gallery, which opens off the chemical mixing floor. Opening off the latter are a finely equipped laboratory, an office and a toilet.

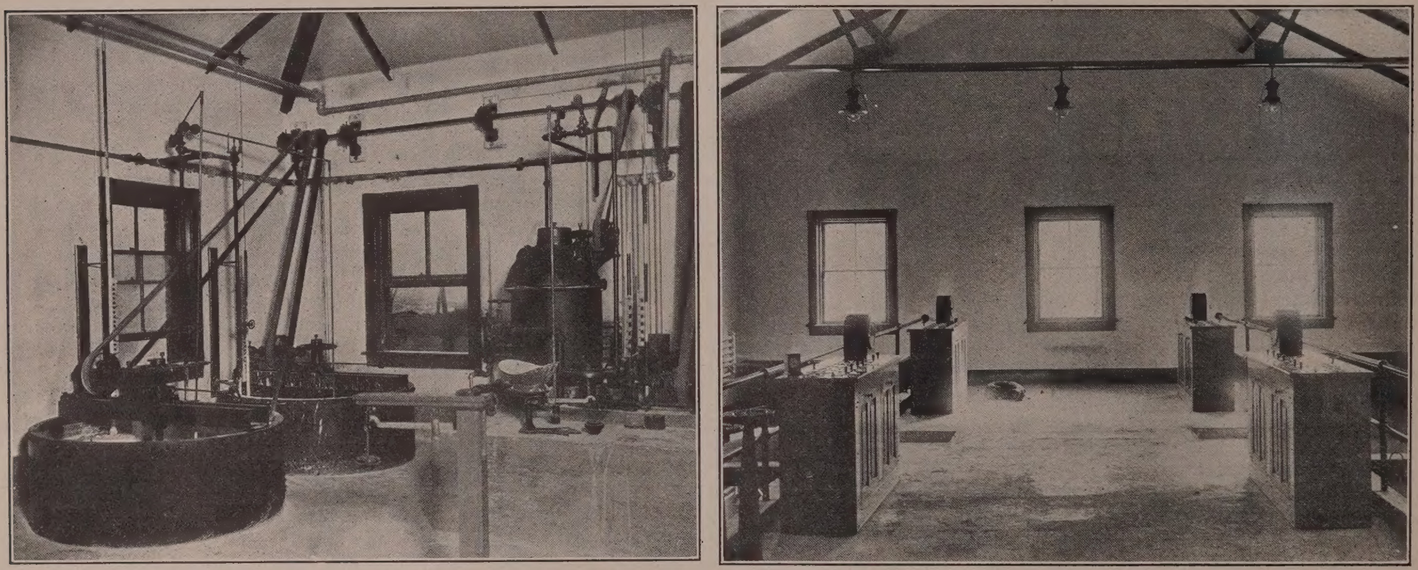
Located on a hill about ½ mile from the plant is the 1,000,000-gal. reinforced-concrete pressure-equalizing standpipe, circular in section, 82 ft. 8 in. in diameter and 27 ft. deep. It is reinforced horizontally in such a manner that the rods act as hoops in taking up tension. In its construction the concrete was placed in sections 24 in. deep, one of these being poured every day until finished.

Operating Features

The water treated, coming from a river which drains a denuded watershed, the soil of which is mostly clay, is subject to marked and rapid changes in character, and bears at all times finely divided clay. The turbidity has been known to increase from 40 to over 2000 parts per million within two hours. The alkalinity is always low, partly because of the influence of mine waste introduced at points along the river and partly because at certain times the addition of lime is necessary to aid in the decomposition of the coagulant. The river, moreover, receives sewage from several towns above. The presence of color in the water is not marked and is never an important factor.

The coagulating basin is operated on the continuous-flow plan, the sections being connected in series. The average period of coagulation is four and three-quarter hours. The velocity of flow within the basin is 1.22 ft. per minute. The settled mud is blown off frequently through the drains and the basin is cleaned thoroughly every six months. In this process the accumulated sludge, which flows readily, is flushed out through the drains by the use of a stream of water, no hand work being necessary. The expense of this is slight, about $8 per cleaning.

In operating the filters a governing factor in the rate of passage through the sand has been the draft on the plant, which, due to the rapid growth of the city, has been greater than its rated capacity—at times by more than 25 per cent. The rate of filtration when the plant is furnishing its normal output is about 150,000,000 gal. per acre daily, or 2.4 gal. per square foot per minute. This rate is higher than heretofore commonly employed in mechanical filter plants of this type. Experience with it would seem to indicate that when water can be economically clarified to a turbidity of less than 30 parts per million rates as high, or even higher, are entirely consistent with perfect clarity of the effluent and, with the aid of hypochlorite, with splendid bacterial purification.



Views of the Chemical Mixing Tanks and Operating Gallery of the Clarksburg Filters

Washing

In washing the filters air is first applied for three minutes at a pressure of 2.2 lb. Following this, wash water is back-flushed through the sand for an average period of five minutes at a pressure of 6.5 lb., and with an upward rate of flow of 8 gal. per square foot of filter area per minute.

In the operation of the chemical system the alum is usually applied between the raw-water pumps and the coagulating basin. At times of extremely muddy river water, however, addition of coagulant at two points simultaneously has effected considerable economy. The hypochlorite has been added to the water after filtration. Upon starting the plant rather higher amounts of the latter were added than at present. These have been gradually reduced until at present about 4.5 lb. per 1,000,000 gal. are sufficient. In the addition of the hypochlorite the use of excessive amounts is guarded against by frequent tests of the treated water with iodine and starch.

In adjusting alum feeds to meet sudden changes in the river water use has been made of diagrams, constructed as data were collected, showing the relations between the turbidity of the raw water, its temperature, and the amounts of coagulant required to give different degrees of clarification.

When the chemical feed has been set it is proportioned to changes in pumpage by attendants, making use of a simple diagram indicating the necessary change in orifice setting. This does by hand regulation what the newer devices, like the Earl regulator, accomplish automatically.

In the care of solution tanks and fittings the corrosive influence of chemicals is minimized by free use of fresh water in flushing them out as soon as the tank in use is emptied. In applying the lime the tank contents are necessarily kept well agitated, but with the alum and hypochlorite solutions clogging of feed lines and orifices is avoided by thoroughly mixing and allowing them to settle just before putting them into service. The strength of the solutions usually carried is as follows: For alum, 3.3 per cent; for lime, 1.7 per cent; for hypochlorite, 0.33 per cent.

Time spent in keeping pulleys and shafting in good alignment and bearings well lubricated and clean is well justified by results. For rapidly running bearings a good grade of engine oil, with a little cylinder oil mixed to prevent its spreading and throwing, is used. Bearings are inspected every day and certain of them are oiled every three hours. In the care of hydraulic valves a very soft waterproof hydraulic packing, kept well lubricated, has been found best. Where this is not obtainable long fiber hemp, braided to fit the stuffing box closely, and well lubricated with cup grease and graphite, is useful.

Considerable trouble was experienced at first from the encrusting of nickel and brass fittings by atmospheric dampness and some hypochlorite dust which unavoidably got into the air. A coating of black metal paint, however, has protected these and preserved them with a neat appearance.

The plant is operated by a chemist in charge and two attendants. The shifts are arranged to overlap slightly, being nine hours long each, so as to give time for repair work requiring two men. Besides looking after the plant as a whole, making reports and keeping records, the chemist makes daily laboratory tests. In keeping records use is made as far as possible of recording gages. Pay sheets, punched for filing, are kept by the attendants, giving essential data covering washing of filters and flow of solutions. Also a card system, a card for each day, is kept, summarizing all the operating and laboratory figures.

In the laboratory the standard methods are used for chemical and bacteriological work. Bacterial counts are made with the use of nutrient agar, the plates being incubated for twenty-four hours at a temperature of 40 deg. C. For B. coli presumptive tests both lactose bile and lactose neutral red broth have been used in fermentation tubes.

The accompanying table summarizes the main points covering results turned out by the plant from January to October, 1912, inclusive.

In the table the samples marked "Filtered" were taken about five minutes after final treatment with hypochlorite, just before being pumped to the city. The B. coli results are average counts estimated from daily fermentation tests. In this connection it may be stated that not a single positive test for B. coli has been obtained in as high as 10 cm. of the filtered water.

The net cost of operating the plant, exclusive of interest and sinking fund, has averaged $5.23 per 1,000,000 gal., distributed as follows: For attendance, $2.52; for chemicals, $2.49; for packing, oil, supplies, etc., 22 cents.

The standpipe, acting as a pressure equalizing reservoir for the city supply, has shown very little evidence of leakage. A slight seep-

Operating Results, Clarksburg Filters, Jan.-Oct., 1912

			Chemicals Added			Turbidity			Bacteria per C.C			B Coli per CC.	
Month	Av. Daily Net Filtered (Mil. Gals.)	Per cent Wash Water	Alum (Gr. per Gal)	Lime (Gr. per Gal.)	Hypo. (Lbs. per M.G.)	Raw	Coagulated	Filtered	Raw	Filtered	Per cent Reduction	Raw	Filtered
January	3.247	1.3	1.84	.58	6.1	67	11	0	940	7	99.26	315	0
February	3.278	1.4	1.82	.60	6.1	110	21	0	810	11	98.64	12	0
March	2.917	1.5	2 21	.90	5.9	189	26	0	1340	11	99.84	637	0
April	3.044	1.5	1.72	.55	6.2	143	20	0	1465	8	99.45	13	0
May	3.023	1.3	0.92	.00	5.4	50	13	0	1970	14	99.24	17	0
June	3.037	1 7	0.68	.00	4.7	84	15	0	1070	11	98.97	27	0
July	2.997	1.7	1.30	.04	5.3	208	16	0	2920	6	99.80	14	0
August	3.014	1.5	0 79	.00	5.3	44	15	0	990	2	99.78	1	0
September	3.024	1.6	1.57	.00	5.5	104	19	0	1865	3	99.84	2	0
October	2.786	1.4	0.73	.00	5.2	30	10	0	410	1	99.76	1	0
Average	3.037	1.5	1.36	.27	5 6	103	17	0	1378	7	99.49	104	0

age through two of the joints between the 24-in. sections, both located near the top of the pipe, was noticed for a short time after it was put into service, but this has gradually decreased after a year's use, until now the tank is, for all practical purposes, thoroughly tight.

Since the introduction of filtered water into the city the typhoid fever, which was formerly very prevalent, has greatly decreased. Undoubtedly this has been due largely to the installation of the filter plant, since other factors affecting this disease have changed but little. The stimulation of the industrial growth of the city due to increased confidence in the municipal water has been of great financial benefit to the community, and great credit is due the local waterworks officials for their initiative in practically rebuilding the entire water system in line with most modern practice and in ample excess of demands made by existing public health laws of the state water.

The plant was constructed for the Clarksburg Waterworks and Sewerage Board, consisting of Mr. T. J. Lynch, president; Mr. S. G. Highland, secretary and superintendent, and Messrs. J. O. Brooks and W. H. Lewis, by the New York Continental Jewell Filtration Company, for whom Mr. W. I. Klein was resident engineer. Mr. J. R. McClintock acted as resident engineer for Messrs Hering & Fuller, consulting engineers. The writer was in immediate charge for the city.

NATURAL CEMENT WAS PRODUCED IN 1912 in fifteen plants distributed in nine states, according to the U. S. Geological Survey, there being no change in the situation compared with 1911 except a decrease in production. The output during 1912 amounted to 821,231 bbl., valued at $367,222, compared with 926,091 bbl., valued at $378,533, in 1911, a decrease of 104,860 bbl., or 11.3 per cent, in quantity and of $11,311, or 3 per cent, in value. The average price of natural cement at the mills in 1912 was 44.7 cents a barrel, compared with 40.9 cents in 1911.

Storing Lime for Water Softening

New Bins and Weighing Apparatus at the Columbus Water-Purification Works

By Charles P. Hoover, Chemist in Charge of Water-Purification Works, and
C. J. Clarke, Engineer, Waterworks Department

At the time the water-purification plant at Columbus was put in operation all of the chemicals to be used in softening and purifying the water were handled and stored in canvas bags. The original chemical storage house consists of one large room, 59 ft. 8 in. wide and 105 ft. long, and has an estimated capacity of 900 tons. The first consignment of lime, consisting of several hundred tons, was delivered in bags, each containing a net weight of 100 lb. The bagged material was stored in the chemical storehouse, but before it could be used it had air slacked and almost all of the bags had burst, demonstrating conclusively the inadvisability of storing lime in bags. Further trouble was also experienced, while using lime delivered in bags, in maintaining a uniform application of the chemical to the water, and it was found that the bags of lime varied in weight from 10 to 15 lb. per bag.

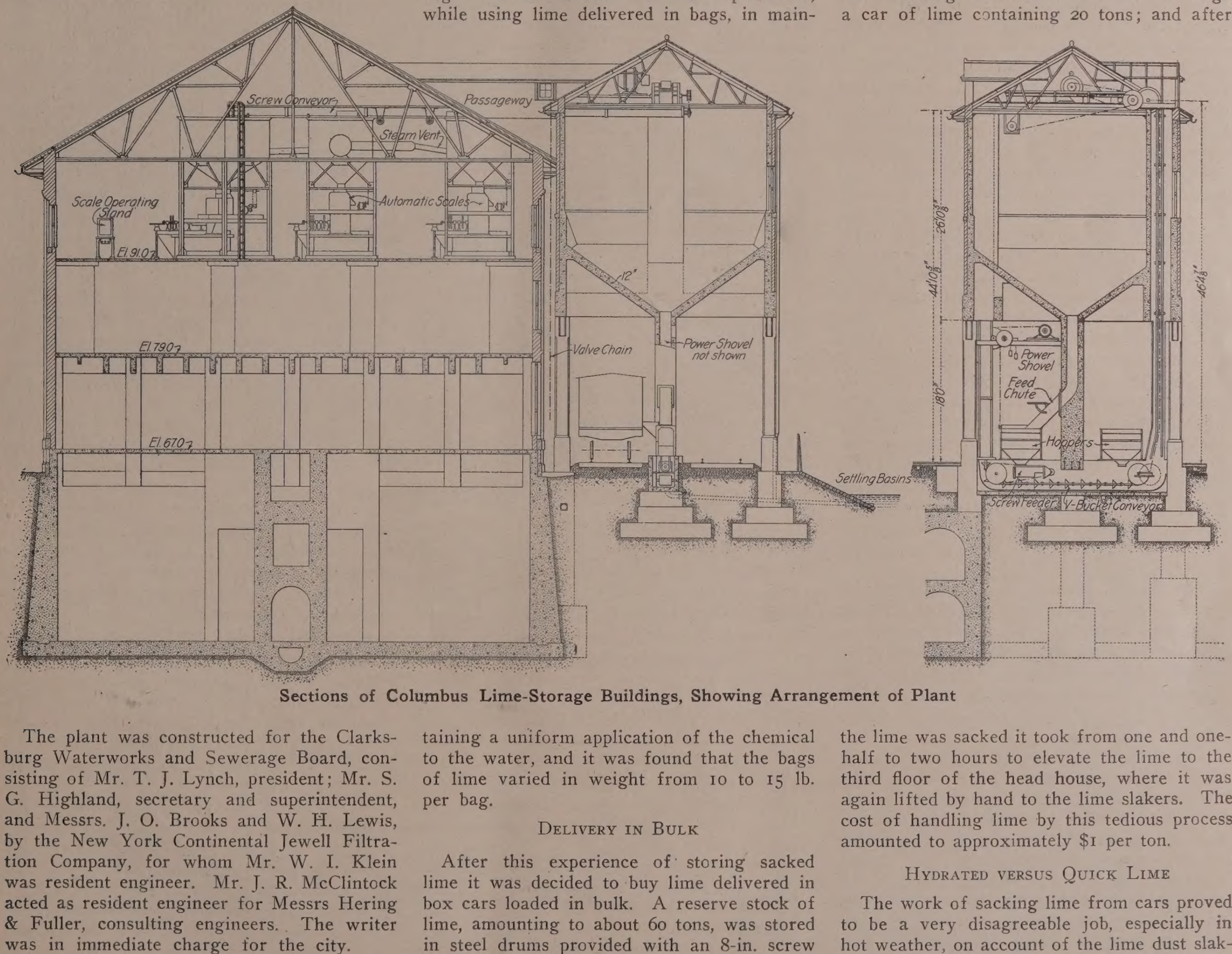
DELIVERY IN BULK

After this experience of storing sacked lime it was decided to buy lime delivered in box cars loaded in bulk. A reserve stock of lime, amounting to about 60 tons, was stored in steel drums provided with an 8-in. screw top. Arrangements were also made with the lime contractor whereby he was to ship the lime at a uniform rate of not less than 40 nor more than 125 tons per week as directed by the chemist in charge of the water-purification works. As soon as it was received the lime was sacked, 90 lb. to a sack, by the workmen at the purification works, and it was planned to regulate the lime supply and shipments so that the lime could be used as soon as received.

The amount of lime necessary to soften the water changes from day to day, and during flood times or after heavy rains the hardness of the river water drops from 300 or 400 parts per million to 100 or 150 parts per million. These changes sometimes occur in less than four hours' time. Consequently there were often six or seven cars of lime on the siding at the plant or in transit in excess of that which could be consumed. Some of these cars were held as long as two weeks before being unloaded because there was no available place to store the excess material. This condition of affairs resulted in a loss to the city, first, because of the demurrage on cars and, second, because the lime air slacked and lost strength. The cost of sacking and weighing the lime was high. It required five men working nine hours to sack and weigh a car of lime containing 20 tons; and after the lime was sacked it took from one and one-half to two hours to elevate the lime to the third floor of the head house, where it was again lifted by hand to the lime slakers. The cost of handling lime by this tedious process amounted to approximately $1 per ton.

HYDRATED VERSUS QUICK LIME

The work of sacking lime from cars proved to be a very disagreeable job, especially in hot weather, on account of the lime dust slaking on the sweaty hands and faces of the men. This slaking of the lime dust often resulted in severe burns and sores. It was thought that the disagreeable features attending the use of quicklime might be overcome by using hydrated lime in its place. Several carload lots of hydrated lime packed in 40-lb. valve type paper bags were received and used. This material was easily stored because the bags were square and could be closely packed, and as the lime had had its affinity for water satisfied there was no trouble from swelling and bursting of bags. The material could be kept indefinitely with-



Sections of Columbus Lime-Storage Buildings, Showing Arrangement of Plant

The Effects of Air Slaking of Lime

out losing strength because it packs into a dense mass, rendering the penetration of carbon dioxide very difficult. However, it did not prove economical or satisfactory to handle and its use was abandoned for the following reasons: Hydrated lime costs more than quick lime. If the hydrated lime is shipped to the plant where it is to be used the consumer must pay freight on a large per cent of water, approximately 30 per cent. It is very difficult to apply hydrated lime to water on a large scale. One of the disagreeable features of using hydrated lime in large quantities is that it "flies" badly, scattering dust through the plant; the dust gets into the eyes, noses and throats of the men handling it. Hydrated lime, according to Monfort, cannot be successfully fed through an orifice, and if fed into automatic scales there is trouble due to bridging. For railroad, industrial or small city water-purification plants, where small quantities of lime are used and where the lime must be stored for long periods of time, hydrated lime is to be recommended in preference to quicklime because it does not air slake and can be kept indefinitely without losing strength.

NEW STORAGE BINS

The storage capacity for lime having become inadequate and the method of handling being unsatisfactory, the superintendent of the waterworks, Mr. Jerry O'Shaughnessy, authorized the writers to prepare plans and estimates for new equipment for handling lime. A description of the plan as finally adopted follows.

The equipment is similar to the installation in use at the coagulating plant of the St. Louis waterworks and consists essentially of a concrete bin, elevated on columns over the railroad tracks located between the head house of the water-purification works and the sedimentation basins; a V-bucket conveyor and elevator for elevating the lime to the level of the head house roof; a screw conveyor for conveying it across and into the head house, where it is dropped into tanks; and three scales for automatically weighing and dumping the lime into the old slaking tanks below.

The storage bin consists of a concrete hopper, 25½ ft. square, with bottom slopes of approximately 38 deg. with the horizontal, heavily reinforced to take the direct pull due to the weight of the lime and the horizontal thrust due to the bulging effect. The main weight is carried on four reinforced-concrete beams, supported in turn by eight columns with flared footings which take bearings on the solid gravel under the track bed. The center column takes part of the load of the hopper and is cored inside with an 18-in. square opening used as a chute to reclaim lime from the storage bin and deliver it by means of the elevator and conveyor to the tanks in the head house.

The lime may be taken directly from the cars to the tanks without passing into the storage bin. The storage bin has a capacity of 220 tons of lime, or about 22 days' supply, which gives ample storage for any emergency. The sides of the bin and slopes of the hopper are designed by formulæ given in "Walls, Bins and Grain Elevators," by Milo S. Ketchum, and are as follows:

$$L = V\frac{1 - \sin\phi}{1 + \sin\phi} \qquad N = V\frac{\sin^2\ (\Theta - \phi)}{\sin^3\Theta\left(1 + \frac{\sin\phi}{\sin^3\Theta}\right)^2}$$

$$T = N\ \text{cot.}\ \Theta \qquad P = \tfrac{1}{2}La \qquad P^1 = \tfrac{1}{2}Lb$$

Where V = vertical pressure at any point in pounds; ϕ = angle of repose of material in degrees; Θ = angle of slopes of hopper with horizontal in degress; L = horizontal thrust due to V in pounds; N = normal thrust on sides of hopper in pounds; T = tangential pull on sides of hopper in pounds; P and P^1 = thrusts at corners of rectangular bin in pounds; a and b = lengths of sides of bin in feet. The angle of repose of lime was taken as 35 deg. and the weight of the lime as 60 lb. per cubic foot.

CONVEYING EQUIPMENT

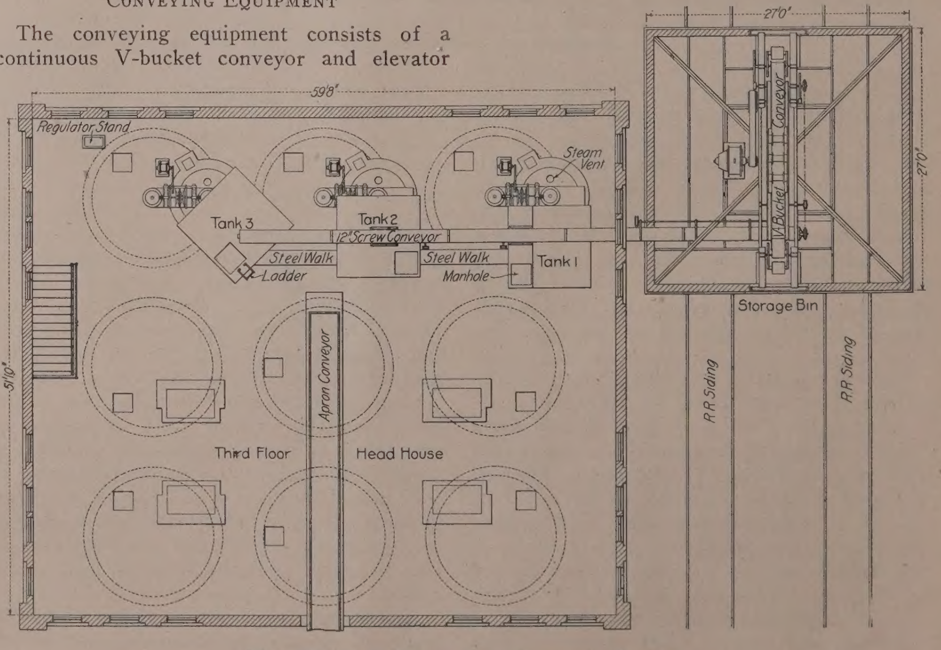
The conveying equipment consists of a continuous V-bucket conveyor and elevator with a capacity of 50 tons per hour, running in a concrete trough between the tracks and through chutes each side of the bin, so that it is inclosed throughout its entire length. The lime is discharged from this elevator into a 12-in screw conveyor which extends into the roof of the head house and discharges into the top of three tanks which are supported on the third floor of the head house on angle columns and extend through the ceiling into the roof space above. The V-bucket elevator and the screw conveyor are operated by an 18 hp Westinghouse direct-current, 220-volt motor, situated in the roof of the storage bin. The tanks are constructed of ¼-in. steel plate, are 8 ft. square, with hopper bottoms, and have a combined capacity of approximately 22 tons, or about two days' supply.

Lump lime, averaging about 2 in. in size, is fed from the tanks into automatic weighing scales, which automatically weigh the lime into slaking tanks. The slaked lime discharges from the slaking tanks into lime-solution tanks below. Milk of lime, of required strength, is made by the addition of water. The milk of lime is kept well stirred by means of paddles and jets of compressed air and is measured into the water by a chemical feed regulator. Later it is planned to pipe the slaked lime directly from the slaking tanks into the water, thus bypassing the lime solution tanks and the chemical feed regulator. The authors are indebted to Mr. W. N. Goodman for the following description of the automatic scales:

AUTOMATIC SCALES

The three automatic scales are alike. Each is built on the equal-balanced-beam principle. On knife edges at one end of the scale beam is suspended the weight hopper and at the other end of the beam, also on knife edges, is suspended the weight box or pan, in which are placed U. S. standard weights to the amount of 75 lb., when that quantity is desired to be weighed. If a 100 or a 150 lb. weight is required, then the actual weight desired to be discharged is placed in the weight box; or the excess of weight over 75 lb. can be added by a sliding counterpoise working on a graduated lever.

The lime is fed to the weigh hopper of the scale down a sloping chute in which is placed a reciprocating plate feeder to keep the lime



Plan Showing Tanks and Conveyor System

from blocking. This feeder is in action only while the scale is filling. It is motor-driven by an electric motor and as soon as the scale has received its load the motor automatically stops.

After being fed down the inlet chute the lime passes through a gate of the undercut type. When the weigh hopper has received four-fifths of its load the gate partially closes, the last one-fifth being dribbled into the hopper. When the exact amount has been received into the hopper the gate closes and is locked by a toggle mechanism. The scale hopper holds the load until it is time to discharge it.

The time of discharge of the three scales is governed by a very ingenious electric clock device specially designed for this job. The scales are connected electrically to the clock and so arranged that one, two or three scales may be discharged as desired merely by throwing in the corresponding switches. Supposing scale No. 1 is required to discharge 100 lb. every minute; it is set to weigh exactly 100 lb. and a one-minute disc is placed on the clock face. At every one-minute interval the clock movement closes a switch which is connected to the scale by means of a solenoid; this solenoid discharges the scale by allowing the weigh hopper door to open. After discharging the load the hopper door closes again and locks itself. In doing so it opens up the inlet gate and automatically starts another weighing, which will be discharged at the right time. The clock can be set to weigh any number of discharges, from 60 per hour down to one per hour.

Each scale is equipped with an automatic stop counter device, so that when a certain quantity of lime is required to be weighed into the slaking tank the counter is set to the number of drafts required, and when that quantity has been weighed the scale will stop automatically. The scales are very accurate, much more so than any hand-weighing methods.

Preventing Steam and Dust

In order to get rid of the steam arising from the water in the slaking tanks, pipes are connected to a suction fan, which draws nearly all the steam away from the scales. To prevent dust and steam from clogging the operating levers of the scales all of the levers are placed outside of the scale proper, which is inclosed in a heavy cast-iron dustproof casing. All of the pins in the scales are made of phosphor bronze and the bearings in which these pins work are bronze bushed, so there is no chance for corrosion to affect accurate and continuous work. The clock device is arranged in a dustproof, lock-up casing, with glass doors, thus preventing tampering with the equipment.

A power shovel for unloading lime from cars into the hopper of the conveyor is located just under the storage bin and supported on the columns. It is operated by a separate 5-hp 220-volt Westinghouse motor, and has unloaded a 40-ton car in about three hours, two men being necessary to do the unloading. While this rate has been adequate for any present requirements, it is not entirely up to the agreement, and better service is looked for later.

Method of Raising Lime Bags by Continuous Elevator

The new installation was put in service Feb. 5, 1913, and it has operated successfully from the start. The total cost of unloading and slaking lime has been cut approximately $3,000 per year. The plans and specifications were checked and helpful suggestions were made by Mr. R. S. Jones, civil engineer, of Columbus, and the construction was supervised by the writers and Mr. Norton, engineer in waterworks department. Mr. James Westwater was general contractor. The elevating and conveying machinery was furnished and erected by the Jeffrey Manufacturing Company, and the automatic scales were furnished and erected by the Richardson Scale Company, Passaic, N. J. The total contract price for the bin and all equipment complete was $17,580. Extras to the approximate amount of $1,393 have been allowed.

Surface Finish for Concrete was given attention by the Board of Water Supply of the City of New York in connection with bridge construction on the Catskill aqueduct, and of several methods examined for securing even, clean textures the use of selected aggregate of pink granite for mortar facing was successful in special cases, according to the board's annual report for 1911. The mixture was poured by the aid of a sheet-iron diaphragm, moved as the backing was poured, the facing and backing being thus placed as a monolith. Experiments showed that the most practical ways of treating concrete surfaces were by pneumatic hammers and by sand blasts.

Prevention of Water Waste in New York

Abstract of Paper Read at Minneapolis Convention, American Waterworks Association, by I. M. De Varona, Chief Engineer, Department of Water Supply, Gas and Electricity

In order to avert the threatening danger of a serious shortage of supply for Manhattan and The Bronx in 1912, and, later, to avoid if possible, the large expense attending the development of additional sources of supply for Brooklyn, which would otherwise have been required to adequately provide for the consumption in that borough until the Catskill water was available, the Department of Water Supply, Gas and Electricity of New York City instituted a vigorous campaign to reduce waste. The intended purpose was fully and most satisfactorily accomplished in both cases. The crisis of 1912, in Manhattan and The Bronx, was tided over, and Brooklyn may now safely await the introduction of the Catskill supply without further developing its watershed.

The estimated daily reduction in consumption in Manhattan and the Bronx reached a maximum of 71 million gallons in August, 1911, averaged 65 million gallons for the last 6 months of 1911 and almost 50 million gallons for the year 1912, while the total reduction since the beginning of the work in the fall of 1910 to April 1, 1913, aggregated over 39,700 million gallons. In Brooklyn the maximum reduction of 34 million gallons daily was effected in February, 1913, and the average daily reduction since August, 1912, the commencement of the house to house inspection, to April 1, 1913, amounted to 25 million gallons, while the total saving since the beginning of the pitometer work in July, 1910, to April 1, 1913, aggregated over 9000 million gallons. This reduction in consumption in the Borough of Brooklyn was such that the average daily consumption for the month of January, 1913, would give a per capita consumption of only 73 gal., which is the lowest per capita consumption for any January since 1894, or for the last 19 years.

The aggregate value of the water thus saved, if figured at meter rates, $133 per million gallons, would be nearly $6,500,000 and the total cost of the work done to effect this saving was about $167,000, which would be reduced to $131,000 if the amount for fines imposed (i.e., $36,000) were deducted.

The per capita consumption for New York City for 1910 (111 gal.) was lower than that of the next five largest cities in the United States, i.e., Chicago, Philadelphia, St. Louis, Boston and Cleveland, for the year 1912; and this in spite of the fact that in New York a floating population of many thousands, not included in the census, is housed, and that there are an equally large number who live outside of the limits of New York City, but who work in the city, also left out of the census. If this transient population were considered, the per capita consumption in New York would be materially reduced. Compared with other American cities, New York, therefore, is economical in the use of water, even if we include our waste.

Preventable Waste

For the purpose of this report, "waste" shall be considered as the quantity of water drawn in excess of that required for the uses already specified, and will be designated as "preventable" when the value of water wasted is greater than the cost of the methods required to save it. For "value" must be understood not simply the normal money cost or selling price of the water, but also the increase or decrease due to the condition of the supply at the time. The author has held before that under existing conditions in New York it would not be advisable in making a safe estimate, to assume a larger permanent saving in consumption from the work to prevent waste, than from 15 to 20 per cent, and the results recently obtained seem to bear out these figures.

Methods for Reducing Waste

The following methods of reducing waste are generally employed:

1. Calling to the attention of consumers the need of checking waste, either for economical considerations or to prevent a threatened shortage on account of inadequate supply, or for both reasons.
2. House to house inspection to detect and repair leaks.
3. Examination for leaks outside of the buildings, in service pipes as well as distribution mains and appurtenances, to locate and repair underground leaks.
4. Metering of all connections where the cost and existing conditions of the supply warrant this measure.

The fourth method cannot under existing legislation be generally applied in New York, nor was it available for the work under consideration.

Public and Individual Notices

Public attention was repeatedly called, through the press, to the inadequate supply available in those boroughs in which existing conditions warranted such a statement, the requisite data being also given in support thereof and the imperative need shown of preventing waste in order to avoid a threatened shortage; while a notice printed in English, Italian and Yiddish was delivered at all premises requiring consumers to stop all leaks in their fixtures, advising them at the same time that the department would impose a fine if after the first inspection leaky fixtures were not promptly repaired. These notices, forwarded about the middle of June, 1911, met with instant and efficient response.

House to House Inspections

The larger portion of waste in the city of New York is due to defective fixtures within the buildings, and especially to the water lost from roof and toilet tanks, and leaks from the latter are also the most difficult to detect, as the escape of water is not always apparent to the eye, although the noise made is sufficient, as a rule, to enable the occupant of the premises to detect the leak. Next to leakage of tanks is that from faucets, due either to their being carelessly left open or to need of repairs usually resulting from wearing out of washers.

The Board of Estimate and Apportionment having approved the issue of $100,000 revenue bonds to pay for a house to house inspection, a force of about 100 inspectors was placed in the field in June, with the necessary clerical force to handle the inspection reports, notices of leakage, etc., this force operating under the direction of the Water Registrar. The Engineering Bureau determined the amount of water consumed before and after house to house inspection, and for this purpose 18 districts were laid out in the borough of Manhattan. The flow into these districts was determined by pitometer measurements, and a record of the reduction in leakage resulting from the inspection was thus obtained. The house to house inspection was continued with full force until September, when the reduction in consumption, together with the increased rainfall, made it unnecessary to prosecute the work as vigorously as in the early part of the summer. At least two inspections were made in each building where leaks were found.

The results of the work done are shown by the following table of consumption, in which the reduction has been approximately apportioned between the work done in stopping leaks in mains and the work done in stopping leaks and waste in buildings:

	Consumption in Manhattan and Bronx, million gallons daily		Estimated consumption assuming increase of 3 per cent equivalent to rate of increase in population	Estimated reduction in consumption, million gallons daily		
Month	1910	1911	1911	By stopping underground leaks	By reducing leakage and waste in buildings	Total
Jan. ..	335	334	345	4	7	11
Feb. ..	336	331	346	4	11	15
Mar. .	327	327	337	6	4	10
Apr...	326	320	336	6	10	16
May ..	326	310	336	8	18	26
June ..	329	286	339	9	44	53
July ..	342	287	352	9	56	65
Aug. ..	336	275	346	9	62	71
Sept. .	335	277	345	10	58	68
Oct. ..	332	278	342	11	53	64
Nov. ..	321	271	331	11	49	60
Dec. ..	333	283	343	11	49	60

Due attention was given to the measurement of flow in pipes and mains outside of buildings, to locate and stop leaks. As investigations made in 1910 had shown some large leaks, especially in mains laid under the East River, and as there was great likelihood of leaks along the river that discharged into it and therefore did not show on the surface, careful measurements were made of the flow of water in various parts of the city to locate these underground leaks, particular attention being given to the river front, and a special division for this class of work was formed, to which were assigned men who had experience in similar work in this and other cities. Broken mains were also found where the loss of water was very great. In one instance, where the broken main lay at the bottom of the East River, the loss amounted to over 3 million gallons per day.

The underground leakage stopped was about 10 million gallons daily, which, if valued at meter rates would amount in a year to nearly $500,000, while the cost of this work, covering a period of about two years, was $19,000, or say $9,500 per year.

Results Obtained

The average daily consumption of Manhattan and the Bronx was 331 million gallons in 1910, giving a per capita consumption of 120 gallons. On the basis of the consumption figures for 1910, assuming an increase of 3 per cent. annually due to increase in population, the average daily consumption would increase to 341 million gallons in 1911 and to 352 million gallons in 1912. By the work to check waste, however, the average consumption for the year 1911 was reduced to 298 million gallons daily, or 105 gallons per capita, but the actual reduction was really greater than shown by the above average, as the effect of the water waste work did not show great results until July, 1911, when the reduction reached 65 million gallons daily and was thus maintained on average up to January 1, 1912.

While there was a natural increase in the consumption for the year 1912, the average daily consumption was only 303 million gallons, corresponding to a per capita consumption of 104 gallons. The consumption for the month of December, 1912, averaged 297 million gallons daily, which is less than the average daily consumption for the year 1904. On the basis of the estimated consumption for 1911, 1912 and 1913 some 39,000 million gallons have been saved, which if valued at meter rates, $133 per million gallons, would amount to about $5,187,000, at a cost to the city of about $100,000, exclusive of the fines imposed for leaky fixtures during the time of house to house inspection. The per capita consumption has been reduced from 120 gallons, which was the average for these two boroughs in 1910, to 101 gallons, which is the per capita consumption for the first quarter of 1913.

Turbine Pumps at Minneapolis

Two two-stage centrifugal, motor-driven pumps of 20,000,000-gal. daily capacity, one installed in each of two old stations raised 99 per cent of all water used in Minneapolis during the year ending May 31. They were put in service May 12, 1912, and have pumped an average of 23,000,000 gal. daily with maximum days of twice this amount; the demand has been heavier since the new filter plant has been started, due to increased connections and to use of water for filter washing. The performance of the pumps was described by Mr. E. P. Burch, consulting engineer, Minneapolis, in a paper before the American Waterworks Association convention, the source of the following notes.

Water is raised 235 ft. from the Mississippi River to the reservoir near the filter plant through a 50-in. steel main 19,000 ft. long laid in 1896. Friction with a 24,000,000-gal. daily rate is 16 to 18 ft. and with 40,000,000 gal. passing, it is 37 ft. When the 54-in. lock-bar pipe, now being laid, is in place the friction will be reduced 66 per cent. The double suction Worthington pumps are driven by 1200-hp, 2200-volt, three-phase induction motors running 514 r.p.m. and were designed to have a pump efficiency of 80 per cent and a combined efficiency of pump and motor of 75 per cent. As originally built the pumps discharged 24,200,000 gal. daily at the required head, so the impeller diameter was reduced 1/8 in. and the angle of the tips slightly changed. The contractor won a slight bonus for efficiency above 80 per cent. On test the motor efficiency was from 94.3 to 94.6 per cent.

Measurement of the water was by Venturi meter and by a weir box, 22 ft. long and 16 ft. wide, baffled at the entrance. The weir was 8 ft. long, design No. 150 of the U. S. Geological Survey. Hook gage readings in the box and 11 ft. away in a protected chamber were recorded. The meter was calibrated from the weir.

Efficiencies during the year averaged about 72½ per cent. One pump impeller had a 3 x 4-in. piece broken out by a brick and the other had a tip broken on the diffusion ring, reducing the efficiency from 2 to 4 per cent. Repairs brought the pumps back to the normal efficiencies.

Electricity costs 0.38 cents per kilowatt-hour, as it is not necessary to pump during the peak loads of the General Electric Company from which power is purchased. This is equivalent to $4.40 per 1,000,000 gal. pumped. One man is on duty each shift.

The New Concrete Drydock at Ferrol, Spain, which was opened May 7 with elaborate ceremonies, is designed especially for naval vessels. It has a length of 724.4 ft. and an entrance width of 122 ft. The depth of water over the sill at low tide is 27 ft., and at high tide 44.5 ft.

The Autoclave Test for Cement

Discussion before the American Society for Testing Materials, at Atlantic City, June 26, and a Report to the Association of American Portland Cement Manufacturers

Results Obtained with the Autoclave Test for Cement

Paper Presented by H. J. Force, Chemist, Delaware, Lackawanna & Western Railroad, before the American Society for Testing Materials

The autoclave test is made as follows: Three neat briquettes are made up, using water which gives a normal consistency on the Vicat needle of from 7 to 10 mm. The briquettes are kept in the damp closet for twenty-four hours, at the expiration of which time they are removed from the molds and placed in the autoclave. Sufficient water is added to partly or wholly cover the briquettes, and the instrument closed. The burners are of sufficient size to raise the pressure to 295 lb. in not more than one hour, and this pressure is maintained for one hour longer, or a total time of two hours. The pressure is then gradually released, the briquettes are taken out and placed in the moist closet for one hour. They are then broken in the standard cement testing machine in the usual manner. The results from the various mills are the average of three briquettes.

Table 1—Results of Tests on Cement from Mill 3

Number of cars represented	Tensile strength, neat, at 24 hr., lb. per sq. in.	Autoclave test				Tensile strength of 1:3 briquettes, lb. per sq. in.			
		Tensile strength, lb. per sq. in.	Change in tensile strength, per cent		Expansion, per cent				
			Increase	Decrease		7 days	28 days	3 months	6 months
1.....	318	40	....	87.39	5.58	332	382	...	...
1.....	297	487	64.00	....	0.75	372	447	...	...
2.....	330	597	80.90	....	0.25	347	390	448	422
1.....	375	472	26.00	....	0.53	295	387	...	...
3.....	392	387	....	1.27	0.41	326	350	432	482
1.....	300	305	1.66	....	1.02	315	397	...	...
1.....	405	528	30.37	....	0.31	346	408	431	...
2.....	392	513	30.89	....	0.10	352	457	450	...
5.....	335	205	....	28.80	1.28	357	...	...	...
Av'ge	349	393	38.96	39.15	1.13	338	402	440	452

Table 2—Results of Tests on Cement from Mill 4

Number of cars represented	Tensile strength, neat, at 24 hr., lb. per sq. in.	Autoclave test				Tensile strength of 1:3 briquettes, lb. per sq. in.			
		Tensile strength, lb. per sq. in.	Change in tensile strength, per cent		Expansion, per cent				
			Increase	Decrease		7 days	28 days	3 months	6 months
6.....	275	508	84.72	....	0.20	406	493	535	414
5.....	402	232	....	42.29	2.77	373	461	478	469
4.....	332	297	....	10.54	1.20	401	471	462	482
2.....	435	555	27.58	....	0.50	331	359	475	476
3.....	473	192	....	59.40	1.87	370	418	483	483
9.....	370	146	....	60.53	3.68	342	399	470	428
4.....	410	525	28.05	....	0.31	373	440	408	452
2.....	350	345	....	1.42	0.25	307	412	406	425
3.....	427	367	....	14.00	0.70	328	352	424	...
1.....	420	27	....	93.57	Soft	408	402	...	...
1.....	364	270	....	26.00	1.97	327	435	...	...
1.....	307	475	54.72	....	...	410	505	...	...
2.....	385	602	56.40	....	...	348	452	544	...
9.....	392	9	....	99.24	Soft	413	443	483	...
2.....	369	64	....	80.00	3.10	355	390	454	...
3.....	378	257	....	31.50	1.92	413	461	470	...
1.....	296	459	16.00	....	0.39	390	473	...	...
1.....	237	630	87.00	....	0.20	416	492	...	...
2.....	429	495	15.40	....	0.80	238	433	...	...
3.....	396	447	13.01	....	1.07	390	453	...	...
Av'ge	372	345	42.54	47.13	1.31	367	437	468	453

A 1 x 6-in. expansion bar is made up with the briquettes and at the end of twenty-four hours is measured and placed in the autoclave. The bar is removed with the briquettes at the end of the two-hour test. The final measurement is made after the bar has remained in the moist closet for one hour.

The tables show the results of all tests on the cements from Mills 1 to 5 respectively. (Two of the tables, showing tests of cements from Mills 1 and 2, are omitted here. All samples, representing 344 cars of cement, passed the autoclave test.) For purposes of comparison, there are shown in Table 4 the averages of the results of all tests from each mill.

Results of Tests

Each shipment from Mill 2 showed a large increase in tensile strength in the autoclave test and with one or two exceptions the expansions were all very low. The chemical composition of the cement from this mill is about normal. The tensile strengths for the sands on the 7 and 28-day and the 3 and 6-month tests were all excellent.

Mill 1 shows, perhaps, the most uniform results of any of the five mills. This is the first mill in the United States to attempt the manufacture of autoclave cement and is the plant at which many of the early experiments were conducted. From the day that they started to make shipments of autoclave cement up to the present time there has not been one single cause for rejection, and this is indeed a most remarkable showing. Mill 1, like Mill 2, shows a continual increase in the tensile strength up to six months.

Mills 4 and 5 also show a wide variation, some of the shipments passing the test, others failing; some showing little expansion, others showing considerable expansion. The results of the 7 and 28-day and the 3 and 6-month tests are lower in this case than in either Mill 1 or 2.

The method of making briquettes used in the laboratory of the Lackawanna Railroad is one of tamping. About 9 per cent of water is usually used and the briquettes are well tamped in the molds by placing an iron die thereon and striking it several times with a wooden mallet. This gives higher results on the 7 and 28-day tests, but when the briquettes are very firmly packed in with the thumbs there appears to be very little difference in the long-time tests, except possibly that more uniform results are obtained by tamping.

Reasons for Failure Under Autoclave Test

To all large users of cement the figures from the various mills are certain to be interesting. The question naturally arises as to why a cement which passes the ordinary boiling test in many cases, from some of the mills, shows a great decrease in tensile strength or goes entirely to pieces in the autoclave test.

Samples of cement which have failed in the autoclave test, when retested again after a period of 30 days, 2 months, 6 months and over a year, in most cases pass the autoclave test. In one or two cases samples which were approximately 15 months old still continued to show no increase in tensile strength; in a few other cases a decrease in tensile strength was shown, while others showed an increase, due to the seasoning process, of over 100 per cent. This points very clearly to the fact that these particular samples were not properly manufactured, for with certain mills any cement which has not passed the autoclave on the first test has in practically every case passed the test after the cement is held for a period of time.

Fine Grinding

Further investigation as to why some of these cements fail to pass this test after a period of time shows that the raw material was more coarsely ground than in other samples which did pass the test after seasoning. The grinding of the raw material and the proper burning play a most important part in the quality of Portland cement; and the author believes that the failure of cement to pass the autoclave test is due very largely to the coarser granules which do not become hydrated when the cement is set up and that the failure of these granules to become fully hydrated is due to their chemical composition. That is, the granules are composed largely of dicalcium silicate ($2CaO\ SiO_2$), with a smaller proportion of tricalcium silicate ($3CaO\ SiO_2$). Granules of this composition

Table 3—Results of Tests on Cement from Mill 5

Number of cars represented	Tensile strength, neat, at 24 hr., lb. per sq. in.	Autoclave test				Tensile strength of 1:3 briquettes, lb. per sq. in.			
		Tensile strength, lb. per sq. in.	Change in tensile strength, per cent		Expansion, per cent				
			Increase	Decrease		7 days	28 days	3 months	6 months
2....	347	504	45.24	....	0.60	385	466	553	491
3....	310	562	81.29	....	0.60	306	362	457	467
6....	242	388	60.33	....	0.75	251	315	407	425
6....	365	392	7.39	....	1.00	345	355	431	452
5....	347	83	....	76.36	4.83	248	287	312	450
18....	233	260	11.50	....	0.91	290	358	416	430
3....	292	472	61.22	....	0.63	312	320	395	396
4....	343	267	....	29.82	2.50	309	380	442	486
4....	275	135	....	60.00	0.40	281	370	407	430
6....	195	410	110.00	....	0.86	328	385	430	446
7....	270	62	....	96.55	2.82	248	355	395	...
4....	268	350	30.70	....	1.20	273	373	472	...
6....	288	80	....	76.60	3.12	305	352	417	...
5....	250	337	53.00	....	0.48	273	346	440	...
7....	193	235	23.68	....	1.50	312	402	483	...
4....	340	435	28.00	....	0.48	339	398	438	...
39....	272	Soft	Soft	....	Soft	352	415	550	...
8....	285	142	....	50.00	1.70	309	372	472	...
1....	370	565	53.00	....	0.23	347	477	...	...
6....	340	Soft	....	Soft	Soft	372	433	504	...
19....	378	Soft	....	Soft	Soft	301	371	532	...
8....	371	Soft	....	Soft	Soft	317	382	509	...
30....	365	25	....	90.41	3.44	328	345	453	...
6....	360	10	....	97.00	4.00	308	363	468	...
16....	275	Soft	....	Soft	Soft	388	438	410	...
6....	352	Soft	....	Soft	Soft	307	435	456	...
6....	385	432	25.90	....	0.52	332	441	524	...
1....	387	532	37.20	....	0.43	355	334	...	...
4....	342	500	46.15	....	0.30	382	424	...	...
6....	372	94	....	80.00	5.40	430	490	430	...
4....	299	70	....	76.60	5.00	413	445	484	...
1....	358	143	....	44.57	3.23	332	390	...	...
2....	261	462	80.00	....	0.52	258	380	...	...
5....	261	374	33.00	....	0.70	233	412	...	...
6....	216	75	....	65.30	No Bar	217	457	...	...
1....	309	494	59.80	....	0.06	...	...	...	...
3....	282	410	45.30	....	0.81	311	395	...	...
2....	387	403	11.10	....	0.68	327	390	...	...
2....	216	440	137.00	....	0.48	361	410	...	...
3....	293	430	47.30	....	0.54	368	466	...	...
1....	308	432	40.26	....	0.36	310	426	...	...
4....	407	325	....	25.23	2.24	370	385	...	...
Av'ge	310	314	49.06	66.80	1.52	320	392	453	447

Table 4—Average of Results of Tests from Mills 1 to 5

Mill No.	Tensile strength, neat, at 24 hr., lb. per sq. in.	Autoclave test				Tensile strength of 1:3 briquettes, lb. per sq. in.			
		Tensile strength, lb. per sq. in.	Change in tensile strength, per cent		Expansion, per cent				
			Increase	Decrease		7 days	28 days	3 months	6 months
1.....	416	687	57.71	....	0.13	393	450	475	463
2.....	407	631	54.53	....	0.27	380	447	486	463
3.....	372	345	42.54	47.13	1.31	367	437	468	453
4.....	349	393	38.96	39.15	1.13	338	402	440	452
5.....	310	314	49.06	66.80	1.52	320	392	453	447

fail to properly hydrate in the period of twenty-four hours and consequently, when brought in contact with heat and pressure, together with moisture, slaking of the dicalcium silicate is quickly brought about, with the result that a large percentage of expansion occurs, together with a proportionate decrease in tensile strength. On the other hand, if the proportion of tricalcium silicate is largely in excess of the dicalcium silicate, then we may expect a more stable product and one which will show considerably less expansion under the autoclave test and remain constant in volume in after years.

In order to produce a large excess of tricalcium silicate two things are necessary—the raw material must be more finely ground and the cement must be burned at a higher temperature. Most of the cement in Mill 2, as well as in Mill 1, shows very little expansion and a comparatively low loss on ignition. It is also known that in both Mills 1 and 2 the raw material was very finely ground. In some of the other mills—for example, Nos. 3 and 4—while the burning was good, the raw materials were not so finely ground; in Mill 5 there was not only fairly coarse grinding of the raw material but there was also a much higher loss on ignition. From the report of Mill 5 it is evident that the cement from this mill could not be as constant in volume as that from Mills 1 and 2.

In order to manufacture a cement which will pass the autoclave test it is necessary to grind the raw material very much finer than is customary and to have the clinker well burned. The manufacturer, however, can greatly increase the output of his mill by grinding his raw material coarser and burning his clinker not quite so hard. This produces a cement which contains a very large percentage of dicalcium silicate, which may not be constant in volume, and which would more than likely fail to pass the autoclave boiling test. This cement would probably require seasoning in order to make it pass the regular boiling test.

FUTURE TESTS

Briquettes for tensile strength from the various mills have been made up on most of the samples shown to one year. It is to be expected that the results on cement for long-time tests will be equally as high, if not higher, than on the standard-specification cements. On the long-time tests for expansion very little difference or variation has been noted to date. A number of expansion bars have been kept under observation and measured at frequent intervals. It is believed that some time must elapse before any difference will be noted in these bars.

A large number of cylinders and cubes have been made up for compression tests. The results to date indicate that higher compressive strengths are being obtained, as a rule, on autoclave cement. A large number of 2-in. cubes of the various brands have been made up for compression tests, to be made during a period of from one to five years. The number tested to date is not sufficient to draw any definite conclusions, except as stated above, that in many cases the autoclave cements show higher strength in compression. The results obtained on autoclave cements are more uniform than on other cements.

MOVING PICTURES OF HEAVY MACHINERY are now being used to demonstrate the operation to prospective customers. This method has been adopted principally by salesmen with Western territories, where long trips would be required to visit machines in operation.

A Study of Available Data on the Autoclave Test

Abstract of a Report to the Association of American Portland Cement Manufacturers by the Institute of Industrial Research, Washington, Dr. Allerton S. Cushman, Director

The high-pressure steam or so-called "autoclave" test is an acceleration method proposed by a prominent railroad in this country. The specifications for it are neither standard nor uniform and the requirements have been changed several times during the last year.

TABLE 1—CRUSHING STRENGTHS OF CONCRETE MADE FROM CEMENTS WHICH DID AND DID NOT PASS AUTOCLAVE TEST

(Each figure is the average of five test pieces)

	No. 15 (Passed test)	No. 16 (Passed test)	No. 20 (Failed)	No. 21 (Failed)
Tensile strength:				
24 hours	351	296	33	407
Autoclave	455	403	0	241
Compressive strength at end of 3 months.	1688	1768	1727	1454
First crack	1444	1661	1609	1339
Compressive strength at end of 6 months.	1900	1936	1973	1875
First crack	1776	1754	1867	1777

All the results embodied in the various tables included in this paper have been obtained by conforming with some one of the specifications proposed for conducting the autoclave test. As it has been conducted in the extended investigations made in the laboratories of the Institute of Industrial Research, the following procedure has been adhered to:

TABLE 2—PER CENT INCREASE OR DECREASE IN TENSILE STRENGTH OF NEAT AND MORTAR BRIQUETTES STORED FOR DIFFERENT PERIODS BEFORE AUTOCLAVE TEST

	Originally passed autoclave		Originally failed	
Sample No.	34	40	35	42
Neat Briquettes:				
24 hours	+40	+32	—41	—82
6 months in water	—30	—30	—27	..
6 months in air..........	—30	— 5	—35	..
7 days water, 6 months air	—27	—26	—37	..
1:3 Standard Sand Briquettes:				
24 hours	+161	+78	+ 9	—20
7 days..............	—11	—38	—11	+62
6 months in water	—30	+ 6	—30	..
6 months in air	—39	—55	—50	..
7 days water, 6 months air	—45	..	—48	..

Six neat briquettes are made by the usual method and allowed to remain in the damp closet for 24 hours. At the expiration of this time the briquettes are removed, three of them are broken in the machine and the other three are placed in a high-pressure steam digester (autoclave) and the pressure raised to 20 atmospheres by applying heat. The pressure of 20 atmospheres is reached within three-quarters of an hour, and is then constantly maintained for one and a quarter hours longer, making a total of two hours under heat. The pressure is then gradually released, the briquettes taken out, and as soon as cool are broken in the standard cement testing machine. The average of the three briquettes taken from the autoclave should show an increase in tensile strength of at least 25 per cent as compared to the average of the three briquettes broken at the end of 24 hours at normal temperature and pressure in the damp closet.

TABLE 3—TENSILE TESTS OF NEAT AND SAND BRIQUETTES TESTED IN AUTOCLAVE AFTER STORING FOR PERIODS NOTED

Cement No.	Test	Tensile strength 1 day Neat	Sand	7 days Neat	Sand	28 days Neat	Sand
2961	Standard	415	...	683	379	775	488
	Autoclave	351	...	373	343	928	455
2959	Standard	448	40	840	406	870	497
	Autoclave	0	0	0	0	0	429
2983	Standard	380	100	767	347	820	375
	Autoclave	536	227	550	384	308	335
2989	Standard	422	20	718	241	662	294
	Autoclave	467	82	358	188	628	306
2990	Standard	349	147	736	264	776	344
	Autoclave	397	174	0	34	628	306
2991	Standard	458	16	761	280	723	390
	Autoclave	0	0	0	0	0	416
2992	Standard	320	86	778	276	804	353
	Autoclave	546	91	253	221	243	365
2993	Standard	275	43	655	264	744	350
	Autoclave	308	101	671	234	803	444
2995	Standard	285	42	712	323	800	383
	Autoclave	278	86	521	201	608	412
3001	Standard	230	73	748	314	947	495
	Autoclave	467	116	193	255	460	491
3004	Standard	295	58	715	304	651	362
	Autoclave	586	335	223	400	260	360
3029	Standard	380	93	591	273	725	368
	Autoclave	336	245	135	155	410	295
8030	Standard	200	14	670	257	751	386
	Autoclave	92	0	0	81	0	287
3031	Standard	213	19	630	236	736	376
	Autoclave	173	10	50	205	0	318
3032	Standard	334	28	751	260	729	328
	Autoclave	0	0	0	0	0	271

In the most recent addition to the specifications for this test it is required that the "briquettes must also develop a tensile strength in the autoclave of at least 500 lb.; the gain in weight of the briquettes must not be greater than 1 per cent. In addition, expansion bars 1 in. square by 6 in. long are to be made up from neat cement and placed in the moist closet, and at the end of 24 hours are to be tested along with the regular neat briquettes. The expansion bars after remaining in the moist closet for 1 hour are to be measured. In no case must the expansion be greater than one-half of 1 per cent. It has been found that cement which will pull about 600 lb. in the autoclave shows an expansion of from 1/10 to 2/10 per cent."

The question of the advisability of adopting this method as an acceleration test must, however, depend principally upon whether or not it can be shown to be rational or to have any true bearing on the qualities of a cement which it is the intention to predetermine. The ordinary boiling and steam-pat test for determining volume soundness, although not altogether rational, has given quite general satisfaction. The supplanting of this simple test by one which is more complicated and which requires more extensive and expensive equipment can only be justified by abundant evidence that the latter furnishes accurate advanced information as to the ultimate behavior of cement in actual use.

HISTORICAL DATA ON AUTOCLAVE TEST

As far as we have been able to determine, the high-pressure steam test on Portland cement was first recommended in Germany by Dr. Erdmenger in 1881. The Erdmenger test was fully investigated by some of the leading German authorities on cements and was rejected by them as inadequate and misleading. This is clearly shown in letters addressed to the secretary of the Association of American Portland Cement Manufacturers. In commenting on the test, Dr. Dyckerhoff states as follows:

"As early as 1881 Dr. Erdmenger recommended in Germany a high-pressure steam test of Portland cement with a view to testing its constancy of volume. This was rejected by the commission on volume constancy in the Royal Bureau of Material Testing (Königliche Materialprüfungsamt), their opinion being based on the fact that such a test had no bearing upon the problems of building construction. At the present time in Germany we consider the high-pressure steam test as being wrong and misleading."

Professor Gary, of the Royal Bureau of Material Testing, writes as follows: "Permit me to inform you that the high-pressure steam test was first recommended by Dr. Erdmenger in our country, but was never put to practical use on a large scale because it was soon discovered that this test was even less adapted to distinguish useless cements from useful cements than the usual methods of determining constancy of volume."

A careful study of all the available data in connection with the historical development of the high-pressure steam test as reported in the transactions of the International Association for Testing Materials shows very clearly that as a quantitative acceleration test the use of high-pressure steam has been generally condemned by leading authorities because it has been found to lead to erratic and inconsistent results.

Influence of High-Pressure Steam on Hardening

Portland-cement briquettes when heated in a high-pressure steam digester may increase in strength, remain unchanged, or deteriorate partially or to the point of falling to pieces. In attempting to account on purely theoretical grounds for this difference of behavior the following important question naturally presents itself: Is this difference of behavior a mark or measure of quality, efficiency or condition in a given cement? If the action of superheated steam is merely to carry out in a few minutes the hardening reactions which would naturally take place in time under service conditions, the question would have to be answered in the affirmative. If, however, the action of superheated steam is to induce a new set of reactions, leading to an artificial, superinduced bond which would never under any circumstances take place under normal service conditions, the question must be answered in the negative.

Table 4—Effect of Varying the Amount of Fine Particles in Cements

Sample No.	Percentage retained on 200 mesh	Tensile strength, 24 hours		Percentage increase or decrease
		Regular	Autoclave	
34	25.1	215	302	+ 40.5
..	40.1	173	248	+ 43.4
40	25.0	348	460	+ 32 2
..	40.0	108	312	+188.9
35	23.9	310	182	— 41.3
..	0.0	335	319	— 4.8
42	18.2	200	46	— 82.0
..	0.0	209	480	+129.6

It is a very well-known fact that if lime and silica in certain proportions are ground together in a slightly damp condition, molded into briquettes and subjected to the action of high-pressure steam, a very strong bond is formed. The reactions induced by the action of the high-pressure steam are the basis of the sand-lime brick industry. Now, a mixture of lime and silica merely ground together in a damp condition would have no hydraulic properties whatsoever, and would never set or develop strength under the conditions which govern the setting and hardening of Portland cements. The sand-lime brick bond has nothing whatsoever to do with a hydraulic bond, and the reactions which account for it are induced entirely under the action of high-pressure steam carried on for a few hours. Unquestionably Portland cement, after being mixed with water, formed into briquettes and allowed to form the first hydraulic bond, contains both hydrated lime and, to some extent, reactive silica. It would, therefore, be expected that on subsequently subjecting it to the action of high-pressure steam, the sand-lime or silica-lime bond would be formed, which might or might not reinforce the natural hydraulic bond already formed.

Table 5—Effect of Varying the Amount of Fine Particles in Cements

Percentage retained on 200 mesh	Tensile strength 24 hours		Percentage increase in autoclave
	Regular	Autoclave	
12	455	722	59
17	435	788	81
22	388	683	76
27	362	632	75
32	457	683	50
37	447	731	64
42	378	745	97
47	323	758	135

An excellent and comprehensive research on the bond formed between lime and silica under the action of high-pressure steam is to be found in a paper published by Mr. S. V. Peppel, entitled "The Manufacture of Artificial Sandstone or Sand-Lime Brick," Bulletin 5, Geological Survey of Ohio, 1906. (See also a very recent treatise entitled "Sand-Lime Brick and Artificial Sandstones in the Philippines," by Cox, Reibling and Reyes, "Philippine Journal of Science," Vol. VII, No. 5, Sec. A.) In his excellent paper Peppel has shown that the strength of the bond formed in the autoclave depends on a number of factors, in which may be included the reactive condition of the lime and silica present. A careful study of this paper and the application of the principles which it develops to the subject under consideration indicates that the action of the autoclave test is merely to produce in addition to the ordinary hydraulic bond a silica-lime bond which can only be produced under the action of high-pressure steam. If this is true, it at once becomes apparent that the autoclave test is not a rational one and should not be used as a method of judging the behavior in construction work of a given brand of Portland cement.

Relation of Autoclave Test to the Development of Compressive Strength

While theoretical considerations are important in judging the value of any test, its real usefulness must rest on the ability clearly to show those qualities which make for better concrete in both short and long periods. In order to determine whether the autoclave test as proposed was able to distinguish between cements which develop their bond normally and properly under service conditions and those which do not, the Institute of Industrial Research undertook a systematic investigation.

A number of different brands of standard Portland cements were purchased in the open market and tested both by the standard methods and by the autoclave test. Out of all these brands tested, four were selected for the purpose of the investigation. One of these absolutely failed under the autoclave test, to the extent that the briquettes made of it disrupted and fell to pieces in the autoclave. Another showed deterioration, while two of the cements passed the autoclave test and increased more than 25 per cent in strength. A large number of 6-in. cylinders were then made from each of these selected cements. They were made from a 1:2:4 mixture, using Potomac River sand and crushed trap rock screened to pass a 1-in. screen. All sets of test pieces were made up as nearly as possible under exactly the same conditions. After they had obtained their final set they were taken out of doors and laid in a sand bed in the form of a tessellated pavement flush with the surface of the ground. They were thus exposed to the normal service conditions which Portland cement concrete may be expected to meet.

At 3 and 6 months' periods a set of five test pieces was removed from each lot and tested under compression in the usual way in a Riehle 150,000-lb. testing machine. These specimens are at the present time not quite 1 year old, but an inspection of the results for the 3 and 6 months' periods, which are given in Table 1, shows that there is little or no difference to be observed between the strength developed by any of the samples of cement, irrespective of whether they passed or failed under the autoclave test. As a matter of fact, the maximum figure for the 6 months' period, as the average of five test pieces, is represented by the cement which gave the worst result of the two which failed under the autoclave test. As far as these tests have gone, it is shown that the autoclave test is not able to distinguish between the strength-developing qualities of cements up to 6 months under normal exposure to out-of-door conditions.

Relation of Autoclave Test to Development of Tensile Strength

In addition to the work described in the last three paragraphs, a very large number of tensile-strength test pieces have been prepared in the laboratories of the Institute of Industrial Research for further investigation of the autoclave test. Autoclave tests made on neat and 1:3 briquettes aged in various ways for periods up to 6 months and prepared from two cements which originally passed and two cements which originally failed under the autoclave test gave erratic results. In general, however, the autoclave test made on all briquettes over 24 hours old, whether stored in air or water, or part of the time in air and the rest of the time in water, showed a decrease in strength as compared to the ordinary standard tests. A summary of the results upon which this statement is based is shown in Table 2.

Table 6—Effect in the Autoclave Test of Adding Raw Material to a Cement

Percentage raw material added	Passing		Tensile strength, 24 hours		Percentage increase in autoclave
	100 mesh	200 mesh	Regular	Autoclave	
0.....	95.0	78.0	524	759	44.8
10.....	94.0	77.0	491	262	0.0
20.....	94.0	77.0	603	701	14.5
30.....	94.0	77.0	443	662	44.4
40.....	94.0	77.0	400	702	75.5
50.....	94.0	77.0	338	605	78.9
60.....	94.0	77.0	226	586	159.0
70.....	94.0	77.0	203	438	115.0
80.....	94.0	77.0	141	333	136.0

Another comprehensive series of results which show that the autoclave test yields erratic results were obtained in a laboratory belonging to one of the members of the Association of American Portland Cement Manufacturers and are set forth in Table 3 (only the first half of this table is reproduced; the remaining tests duplicate more or less those given).

Table 7—Percentage Contraction in Air and Expansion in Water of Cements Which Did and Which Did Not Pass Autoclave Test

Sample	B	C	D
Boiling test	..	Passed	Passed
Autoclave test	Passed	Failed	Expanded considerably
Expansion under autoclave test	0.15	...	2.80
Percentage contraction in air:			
After 3 days............	0.05	0.10	0.10
After 7 days...........	0.20	0.15	0.20
After 14 days..........	0.25	0.25	0.25
After 21 days...........	0.25	0.20	0.25
After 28 days..........	0.30	0.25	0.25
After 3 months.........	0.30	0.30	0.25
After 6 months.........	0.28	0.25	0.20
Percentage expansion in water:			
After 3 days...........	0.00	0.00	0.00
After 7 days...........	0.10	0.05	0.05
After 14 days..........	0.05	0.05	0.05
After 21 days..........	0.10	0.10	0.10
After 28 days..........	0.05	0.10	0.10
After 3 months.........	0.30	0.30	0.30
After 6 months.........	0.28	0.30	...

It is a well-known fact that under standard tests briquettes stored in air and water increase in strength with time up to an average maximum. The fact, however, that properly aged briquettes show a decrease in strength when tested by the autoclave test indicates the truth of the statement made in an earlier paragraph—that a silica-lime bond is formed under the action of the high-pressure steam, in the first place, which later on is apparently not produced. Attention is called to the fact that erratic results are shown in a great number of cases. It would appear from this analysis that the autoclave test was not capable of indicating the useful qualities in any brand of Portland cement.

Fineness of Particles

In the investigations carried out in the laboratories of the Institute of Industrial Research efforts were made to determine the effect of varying the size of particles in a given brand of cement in its relations to the results obtained by the autoclave test. By means of standard screens a given brand of cement was sized into different-sized particles and could then be recombined and the grading of different-sized particles varied. The following facts were developed by this phase of the investigation as shown in Table 4.

Doubling the particles retained on the 200 mesh and thereby increasing them from 25 to 40 per cent in two cements which passed the autoclave test raised the percentage increase in strength of the autoclave test, although in both cases the actual or standard tensile strength was lowered.

Removing the particles retained on the 200 mesh in two cements which failed to pass the autoclave test caused a much lower percentage decrease in one case and a 129 per cent increase in tensile strength in the other.

In another investigation made in a laboratory of a member of the association the results of a large number of tests show that increasing the percentage of particles retained on the 200 mesh from 12 to 47 per cent gave erratic results under the autoclave test. For 12, 17, 22, 27, 32, 37, 42 and 47 per cent coarse particles the autoclave test shows 50 per cent increase in strength or over, as compared with ordinary test. Forty-seven per cent coarse particles gave the highest percentage increase in strength (135 per cent), while 32 per cent coarse particles gave the lowest increase in strength (50 per cent). The results of these tests are fully set forth in Table 5.

In other investigations made in laboratories of members of the association the results of a large number of tests corroborate the results of Table 5 and show that coarse particles in cement do not prevent it from passing the autoclave test.

Miscellaneous Tests

Extra-Fine Grinding of the Raw Mix.—In another laboratory belonging to a member of the association the question was investigated as to whether fine grinding of the raw mix is a factor in respect to the manner in which the finished cement will stand the autoclave test. Out of seventeen samples, of which from 94.8 to 96.2 per cent of the raw mix passed 100 mesh, four samples failed under the autoclave test. In all cases the fineness of the finished cement particles was approximately the same.

Adulteration of Cement by Grinding in Raw Material.—The results obtained in the laboratory of a member of the association show that adulteration of cement by the addition of varying percentages of raw material in the grinding operation show an increase of 44.8 per cent of strength under the autoclave test and that the results were erratic. The addition of 10 per cent of raw material shows a loss in strength under the autoclave test, while the addition of 40, 50, 60, 70 and 80 per cent of raw material shows a percentage increase in strength under the autoclave test of from 75.5 to 136 per cent. These results are set forth in detail in Table 6.

Percentage of Gypsum or Plaster in Grinding Portland Cement.—The results obtained in the laboratory of another member of the association show that the addition of extra quantities of gypsum in the grinding decreased the strength under the autoclave test of a sample that originally passed the test, while the addition of gypsum to a cement that failed to pass in another case increased the strength under the autoclave test, although it did not push it up to the passing point.

Miscellaneous Tests.—In a laboratory of a member of the association the results of a number of tests showed that cements which do not pass the autoclave test do not necessarily contract in air or expand in water to a greater extent than cements which successfully pass the autoclave test. These results are set forth in Table 7.

Conclusion and Summary

The effort has been made in this paper to analyze fairly all the data available at the present time which bears upon the value of the autoclave or high-pressure steam test as a method of determining the efficiency, quality or condition of a Portland cement.

A careful examination and analysis of all the data obtained in various laboratories and the experience of the Institute of Industrial Research, gained during a systematic investigation of the autoclave test, show that it yields erratic results and is not to be depended upon for determining a quality or condition of any brand of cement either for immediate or future results in service. The conclusion which must be reached as the result of these investigations is that the test is not dependable as a method of distinguishing cement which will give successful results from the cement which may be expected to fail under service conditions.

Value of the Autoclave Test

Abstract of a Discussion before the American Society for Testing Materials, by Rudolph J. Wig, of the Bureau of Standards, Washington, D. C.

The purpose of the tests herein described was to ascertain in a general way the effect of high-pressure steam on Portland cements as found on the market and to compare such physical properties as linear expansion, compressive strength and tensile strength of so-called sound cements with like properties of cements found to be unsound in high-pressure steam.

Routine Soundness Tests

In order to ascertain just what proportion of the cements as at present manufactured were sound in high-pressure steam all routine samples received in the laboratory were subjected to a high-pressure steam test, and the results are shown in Table 1. As the amount of cement that could be spared from the routine sample was necessarily small, the standard-soundness pat was used as a test piece in place of the briquettes. A sample was said to pass the high-pressure steam test when the pat remained sound after being subjected to a steam pressure of 300 lb. for 1 hour, the total time in autoclave being 3 hours.

Table 1.—Results of High-Pressure Steam Tests on Portland and on White Portland and Natural "Non-Staining" Cements

	Portland	Non-staining
Number of samples	564	61
Samples sound	438	51
Samples unsound	126	10
Brands sound	35	5
Brands unsound	16	1
Brands sound at one time, unsound at others*	6	1

*These brands are included in two previous classifications.

The purpose of this test was to ascertain the comparative linear expansion of cements which were sound and unsound in high-pressure steam.

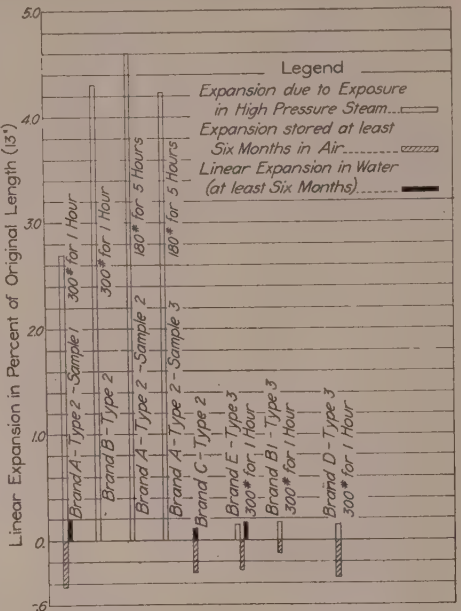


Fig. 1—Expansion of Sound and Unsound Cement in Autoclave

The test pieces, which were 1 x 1 x 13-in. neat cement prisms, were stored in air, stored in water and treated in high-pressure steam, and the linear change of test pieces under each condition was studied. The amount of expansion was found by means of a mounted micrometer screw which read to ten-thousandths of an inch, and the expansion is expressed in per cent of the original length (13 in.).

In these tests a cement was said to have passed the high-pressure steam test when in the form of a standard-soundness pat it remained sound when subjected to a 300-lb. steam pressure for 1 hour; total time in autoclave, 3 hours. Cement passing the 212-deg. Fahr. steam test, but failing in the high-pressure test, was called Type 2 cement, while cement passing both tests successfully is reported as Type 3 cement.

The comparison of the expansion or contraction of cement in air, water and high-pressure steam is shown diagrammatically in Figs. 1 and 2.

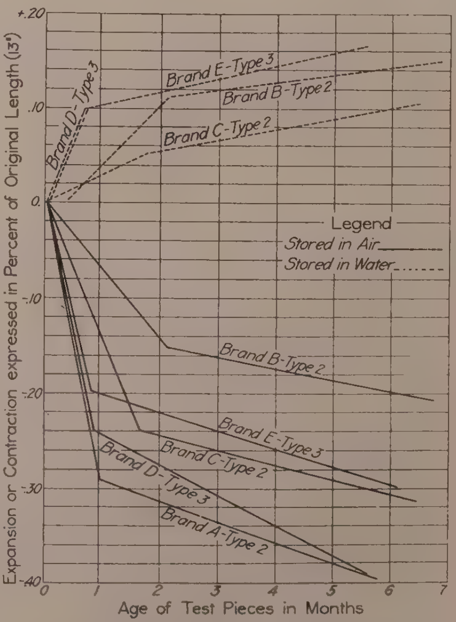


Fig. 2—Expansion in Air and Water

Type 2 unsound in autoclave; type 3 sound in autoclave test.

Effect of Variation in Steam Pressure on Linear Expansion.—Linear-expansion test pieces of 7 cements were made, stored in a damp room for 24 hours, then subjected to 100 lb. steam pressure for at least 5 hours, then the linear expansion was determined. These same test pieces were then subjected to 180 lb. for at least 5 hours, and in some cases to 275 lb. for 5 hours and the linear expansion determined. The results of these experiments show that the linear expansion at 100 lb. steam pressure is less than that at the higher pressures (180 to 275) by an average of 2/100 of 1 per cent.

Expansion or Contraction Subsequent to Treatment in High-Pressure Steam.—Several of the expansion test pieces were placed in air and some in water after they had been treated in high-pressure steam (180 lb. for 5 hours), and the linear change was found at various intervals. Results of these tests show that after storing a month in air, subsequent to treatment in high-pressure steam, the average change is less than 1/100 of 1 per cent, while 6 months after the steam treatment the test piece has changed an average of less than 5/100 of 1 per cent. In water less than 1 month after steam treatment the average change in length is less than 3/100 of 1 per cent.

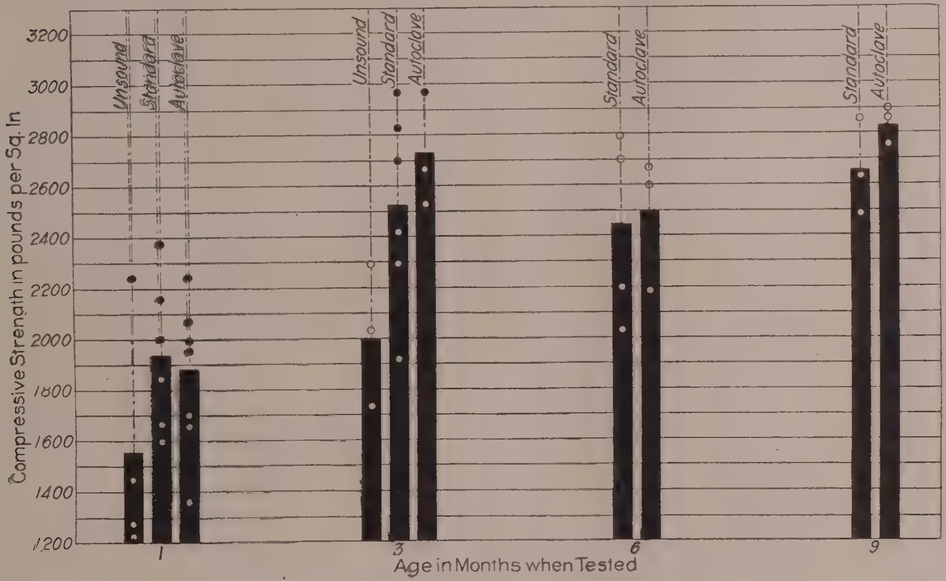


Fig. 3—Compressive Strength of Concrete Made with Various Cements

Effect of the Addition of Sand to Cement.—To one cement failing in the high-pressure steam test (Type 2) an equal part of standard Ottawa sand was added and the linear expansion after subjection to high pressure steam (180 lb. for 5 hours) was determined. A similar test piece of a 1:2 mixture of cement and sand was made, treated and tested as above. It was found that the linear expansion of the 1:1 mortar was 96 per cent of that of the neat cement and the 1:2 mortar was 69 per cent of that of the neat cement. All test pieces received the same steam treatment.

Effect of Fineness on Soundness of Cement

A cement passing the standard fineness and soundness tests but showing unsoundness in the form of a pat in the autoclave at 300 lb. for 1 hour—total time in autoclave, 3 hours—was separated into that passing the 200 sieve and that retained on the 200 sieve.

Each kind was made into a neat cement pat and subjected to 300 lb. steam pressure for 1 hour; total time in autoclave, 3 hours. The pat made of cement retained on 200 sieve completely disintegrated, but the pat made of cement passing the 200 sieve showed no signs of disintegration, cracking or warping.

A mixture of 1 part cement passing the 200 sieve with 1 part retained on the 200 sieve when made into a pat and treated in steam at 300 lb. for 1 hour—total time in autoclave, 3 hours—completely disintegrated. A mixture of 1 part cement retained on the 200 sieve with 2 parts cement passing the 200 sieve also disintegrated, but in this case the disintegration was not so marked or complete.

Many of the samples reported as sound in high-pressure steam under "Routine-Soundness Tests" were relatively coarse cements—i.e., only 76 to 80 per cent passing the 200-mesh sieve.

One cement having 79 per cent passing the 100-mesh sieve and 61 per cent passing the 200-mesh was sound in high-pressure steam.

The coarse material retained on a 200-mesh sieve was removed from a cement which was sound and showed the 25 per cent increase in tensile strength after exposure to high-pressure steam. It was tested and found entirely to disintegrate in the form of a pat in high pressure steam.

Effect of Age and Various Steam Pressures

About 30 samples of cements, all sound in the standard steam test but unsound when subjected in the form of a pat to 300 lb. steam pressure for 1 hour—total time in autoclave, 3 hours—were stored in airtight glass jars and retested in high-pressure steam at various intervals. The results of these tests indicate that a cement originally unsound in high-pressure steam will become sound if permitted to age from 2 to 6 months.

Table 2.—Effect of Various Steam Pressures on Tensile and Compressive Strength of 1:3 Portland Cement, Standard Ottawa Sand Mortar

Cement	Steam pressure lb.	Tensile strength in lb. per sq. in.		Compressive strength in lb. per sq. in.	
		Age 48 hrs.	Age 28 days	Age 48 hrs.	Age 28 days
A.....	10	118	261	....	....
A.....	20	117	218	1915	2591
A.....	40	115	190	1176	2262
A.....	60	151	215	1750	2385
A.....	80	195	260	1890	2178
A.....	100	294	315	3397	2867
A.....	100	381	366	....	....
A.....	100	514*c*	425*c*	....	....
A.....	120	385	358	2485	2353
A.....	140	410	411	2965	2537
A.....	160	363	355	2912	2327
A.....	180	362	286	3198	3050
A.....	180	369*a*	256*a*	3416	3079
A.....	180	398*b*	272*b*	....	....
B.....	200	245	288	....	....
B.....	275	218*d*	193	....	....
B.....	225	211*e*	219	....	....

a, 2 periods of 5 hours each; *b*, 3 periods of 5 hours each; *c*, age 7 days under pressure of 100 lb. for 15 hours; *d*, exposed to 1 period of 5 hours at 200-lb. pressure, then 1 period of 5 hours at 275 lb.; *e*, exposed to 5-hour periods each at 200-lb., 275-lb. and 225-lb. pressure.

Note.—All subjected to steam at stated pressures for 5 hours unless otherwise noted. Both cements A and B passed the standard soundness test. All test pieces placed in boiler after 24 hours in damp room. All values are the average of three test pieces.

On most of the above cements a number of pats were made up at a time when the cement was unsound in high-pressure steam. These pats were stored and tested at subsequent intervals in high-pressure steam. In all cases these pats when subjected to high-pressure steam disintegrated as in the original test. This indicates that, after hydration, age has little or no effect on soundness of cement in high-pressure steam.

A study of the effect of various steam pressures on cements passing the standard steam test is shown by Table 2. This table includes results of tests of steam-treated specimens when 2 days old (just after removal from autoclave) and similar results of tests when the steam-treated specimens are 28 days old. The results show that after the steam pressure has been raised to 100 lb. there is practically no increase in either compressive or tensile strength from 48-hour to 28-day tests. The maximum tensile strength appears to have been attained with 140-lb. steam pressure. The maximum compressive strength had not been reached at 180 lb. steam pressure.

Comprehensive Strength

Seventeen sets totaling 765 concrete cylinders 6 in. in diameter by 16 in. in length were made of 1 part Portland cement, 2 parts river sand, and 4 parts river gravel mixed to a mushy consistency to be tested at various intervals up to 10 years. In seven of the sets the cements used passed the standard 212 deg. Fahr. steam test, and when subjected in the form of neat briquettes to 300 lb. steam pressure for 1 hour—total time in autoclave, 3 hours—showed an increase in tensile strength of at least 25 per cent over the untreated cement of the same age. These tests of cylinders are said to contain Type 3 cement. Six sets contained cements that passed the standard 212 deg. Fahr. steam test, but failed to give 25 per cent increase in tensile strength and were unsound in the form of a pat when subjected to 300 lb. steam pressure for 1 hour—total time in autoclave, 3 hours. These are designated as Type 2 cements. Four sets of cylinders contained cements which failed to pass the standard 212 deg. Fahr. steam test. The cements in these cylinders are referred to as Type 1 cements. Seventeen different samples of 7 different brands of cement are included in this series of tests and in some cases there are 3 types of one brand.

Fig. 3 shows the results up to the 9-month period in so far as the tests have been completed. All test pieces were stored in air, subject to atmospheric conditions.

Summary

This summary should be considered as tentative, few of the tests extending over more than 9 months, and many of them being only of a preliminary nature.

1. Eighty-eight per cent of the brands of a total number of 48 brands tested passed the autoclave requirement upon some tests; 52 per cent of the brands passed upon all tests and 6 brands failed to pass the autoclave upon all tests.

2. There is no difference in the linear expansion between Type 2 and Type 3 set cements which are exposed in the atmosphere for a period of 6 months.

3. There is no difference in the linear ex-

pansion between Type 2 and Type 3 set cements which are exposed to fresh water for a period of 6 months.

4. The linear expansion of different cements varies from 0.135 to 4.2 per cent of the original length when exposed to steam at pressures between 180 and 300 lb. per square inch. The Type 3 cements had an expansion below 0.2 per cent and the Type 2 cements had an expansion above 2 per cent.

5. The linear expansion of set cements exposed to steam increased slightly as the steam pressure was increased. (Samples tested show an average increase of 0.02 of 1 per cent for pressures ranging from 100 to 275 lb. per square inch.)

6. Set cements show very little change in volume upon storage in air or water after being subjected to high-pressure steam.

7. Samples of apparently sound cements and concretes have been taken from structures 1 year or more old and found to disintegrate upon being subjected to high-pressure steam. Samples of concrete of poor quality have been taken from structures 1 year or more old and found to show no physical change upon being subjected to high-pressure steam, while other samples of concrete of apparent poor quality entirely disintegrated.

8. The expansion of a 1:1 or 1:2 cement sand mortar made with Type 2 cement exposed to high-pressure steam shows more than 50 per cent of the expansion of the same cement neat exposed to high-pressure steam.

9. Of cements which are normally unsound in the ordinary atmospheric steam or autoclave steam test, if the finer size particles are removed, they will be found more sound if tested in the same manner as the original cement, and in many cases entirely sound. While fineness is not essential to soundness, it is the coarser particles of a normally unsound cement which cause the expansive action.

10. A cement originally unsound in the autoclave test will usually become sound in 2 to 6 months.

11. If the cement is hydrated and formed into a test piece while it is unsound it will not become sound upon aging for several months, even though the test piece is stored in water.

12. The maximum tensile strength of sound cement exposed to steam appears to be attained at a pressure not exceeding 150 lb. per square inch.

13. The compressive strength tests of concretes made from the three types of cement—No. 1 cement failing to pass the standard atmospheric steam test, No. 2 cement passing the standard steam test but not passing the autoclave test, No. 3 cement passing both the standard steam test and the autoclave test—show a tendency for Type 1 cements to develop the least strength and Type 3 cements the greatest strength, although the range of values is not very great, and these results should be considered somewhat tentative.

Sufficient data have not been advanced to justify a conclusion as to the merits of the proposed autoclave test of cement, nor to warrant its adoption into a specification; but further investigation should be made and due consideration given to a hot test of greater severity than the present standard steam test.

Contradictory Figures in Tests by the Autoclave Method

Discussion by L. R. Ferguson before the American Society for Testing Materials

I desire to draw further attention to the significance of certain of the figures given in the paper by Mr. Force.

First, the question of the amount of expansion which a cement shows in the autoclave will be taken up. I have understood that Mr. Force claimed that the cement showing the least expansion in the autoclave would show ultimately the greatest strength. Judging from the tests shown in Mr. Force's paper, this conclusion is unwarranted. Of the samples of cement from Mill 1, the ones which showed a decrease in tensile strength between the three months' and the six months' periods have less expansion in the autoclave than the cements which showed an increase between these periods.

In the tests from Mill 2, the sample which gave next to the greatest strength at six months had an expansion in the autoclave of 1.5 per cent, and the sample having the least expansion, 0.10 per cent, has the least strength at the age of six months.

In the tests from Mill 3, of the two tests given at the six months' period the one having the greater expansion has the greater strength.

In the tests from Mill 4, the cement showing next to the greatest decrease in the autoclave gives the greatest strength at the age of six months.

In the tests from Mill 5, the cement which gave a tensile strength of 450 lb. at six months, slightly higher than the average, showed an expansion of 4.83 per cent—the greatest expansion shown for cements covered by the six-months' period.

I understand also that Mr. Force claimed that in certain cements there exist coarser granules which do not become hydrated when the cement is set up. These coarser granules are supposed to cause a lack of constancy of volume in the mortar or concrete when they do hydrate. The autoclave is supposed to detect the presence of these coarser granules. If such is the case it would be supposed that cements which show a decrease in strength in the autoclave would show a decrease in strength between certain periods and that a cement which showed increased strength in the autoclave would show a steady increase in strength with age. Taking Mr. Force's figures from the various mills he has tested, we find that this is not the case. As a matter of fact, the average of the cements which gave an increase in the autoclave invariably show a retrogression in strength between the age of three and of six months, while the average of the cements which gave a decreased strength in the autoclave show a steady increase as far as the tests have been carried, with practically no retrogression. These results are shown in the diagrams, Figs. 1 to 5.

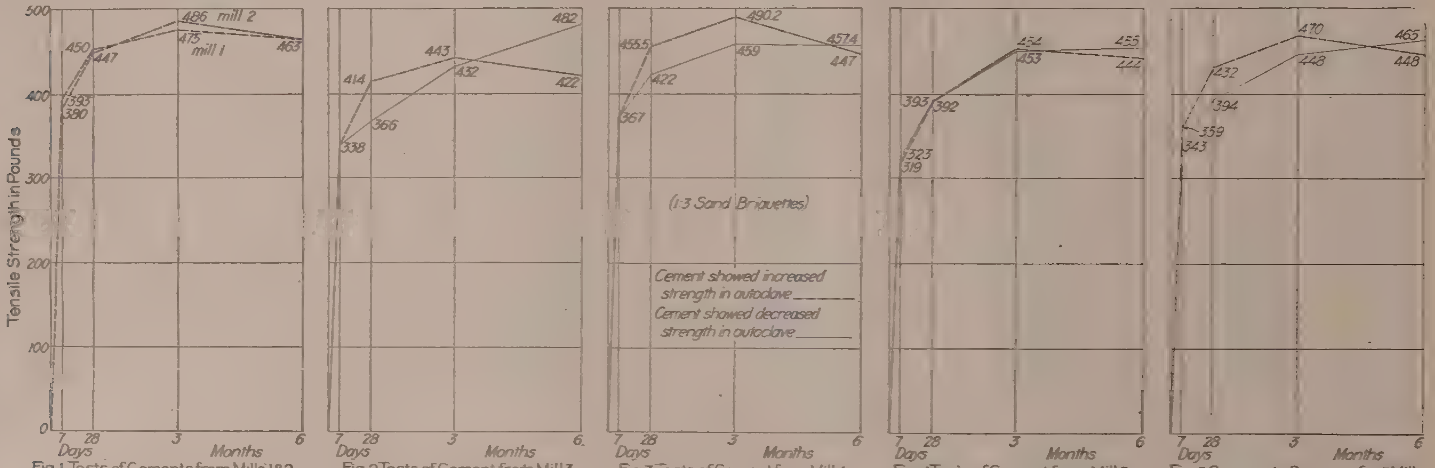


Fig. 1 Tests of Cements from Mills 1&2 Fig. 2 Tests of Cement from Mill 3 Fig. 3 Tests of Cement from Mill 4 Fig. 4 Tests of Cement from Mill 5 Fig. 5 Composite Diagram for 5 Mil'

Figs. 1, 2, 3, 4 and 5—Curves of Tensile Strength of Cements, Showing Increases or Decreases in Autoclave

Analysis of Test Results by the Autoclave Method

Discussion by Henry S. Spackman, Consulting Engineer, Philadelphia, before the American Society for Testing Materials

Mr. Force's paper is of great importance to all manufacturers and users of Portland cement, not because of the discussion it has aroused, as to the value of the autoclave test per se, but because it raises the question of the value, for predicting behavior in the work, of the tests prescribed by our standard specifications for constancy of volume.

It is generally recognized that change in volume of concrete construction is due to three causes, two of which are temporary, i.e., change in volume due to temperature changes and expansion and contraction due to variation in the moisture present in the concrete; the third change in volume is permanent and is due to the expansion consequent on the retarded hydration of the lime compounds in the cement. The extent of movement in the first two causes can be predicted and taken care of in the design of the structure and causes no loss in strength if the structure is free to accommodate itself to them. The third is, as yet, an unknown quantity, and its value is entirely a matter of speculation, and is possibly variable with each cement. It is not detected as far as my investigations go, by ordinary test for soundness and I am disappointed in Mr. Force's paper, as I had hoped that Mr. Force's further investigations would show a definite relation between the ability of the cement to pass the autoclave test and its subsequent stability or lack of permanent change of volume when used in the work. And in this disappointment I feel all manufacturers of Portland cement will share, for I feel confident that they are equally as desirous as are engineers for the formulation or development of a test which will be positive for determining the freedom from disintegration of concretes or mortars made from their product, caused by the expansion of a portion of the cement after initial hardening.

I have long been of the opinion that certain internal strains may be developed in structures depending for their binding effect upon Portland cement by the expansion of the intermediate-sized particles of cement. In such cases the durability of these structures depends on whether the cohesive force developed exceeds the expansive force due to the retarded hydration of the intermediate-sized particles. It is to this that I attribute the drop often observed when cement is tested over long periods under tension. While I fully recognize that under actual working conditions concrete would rarely, if ever, be subjected to conditions such as those found in the autoclave test, this, to my mind, does not constitute a reason for condemning the test, provided it can be shown that there is a relation between the effect produced by these abnormal conditions and the effect of time under normal conditions, but so far the published results of tests made with the autoclave, including those in Mr. Force's paper now under discussion, fail to show this relation or that cement passing the proposed tests will give greater strength over long-time periods.

Reconsideration of Tests

Considering Mill 1, from which all the cement passed the autoclave tests, the average at the six-months' period, though incomplete, due to the fact that a number of the tests are not carried to the six-months' period, shows a reduction in the tensile strength of 12 lb. Considering only the tests that extend to the six-months' period, we find that the 1:3 sand briquettes show in the three-months' tests an average of 462, and at six months an average of 462, or no gain. An analysis of the individual breaks, however, shows that out of the eleven tests carried to the six-months' period, all of the cements passing the autoclave tests, five show retrogression while six show a gain.

Considering Mill 2 we find that while all cement passed the autoclave test, that the average, including the short-time tests of cement not carried to the six-months' period, show a retrogression of 23 lb. between the three and six-months' periods and of the five tests carried to the six-months' period, three show retrogression and two show gains.

Turning to Mill 3, where out of nine tests three failed to show an increase when tested in the autoclave, the average, though incomplete shows a continued gain in strength up to the six-months' period. But of the two cements carried to the six-months' period the one showing the largest increase under the autoclave shows a loss of 20 lb., and the one showing a decrease of 1.27 shows an increase of 30 lb.

The same conditions will be found by an analysis of tests of Mill 4. The average of all tests show a decrease in strength under tension at the six-months' period. Considering the eight tests which are carried to the six-months' period, we find that three showed an increase in strength under the autoclave tests and five a decrease; that of the three cements showing an increase under the autoclave test one showed a marked decrease at six months over the three-months' period, amounting to 121 lb., or over 20 per cent. The other two show gain. Of the five tests showing a decrease when tested under the autoclave, two show a decrease and three an increase at the six-months' period; the average of the cements passing the autoclave test at three months being 473 lb.; the average of the same tests at the six-months' period being 447, or a decrease of 26 lb. Of the five cements showing a decrease under the autoclave test, the average at three months is 460 lb., while at the six-months' period these cements showed an average of 457 lb., or a decrease of 3 lb. against 26 lb.

In the cements from Mill 5 the average, which again includes a number of results obtained at the seven-day, twenty-eight day and three-months' period which have not been carried to the six-months' period, we again see a decrease at the six-months' period, over the three-months' period for average of all the tests.

Six Months' Tests

Analyzing the tests carried to the six-months' period, we find seven showing an increase under the autoclave test and three a decrease; and that the seven passing the autoclave test show an average increase at six months over the three-months' test of 3 lb. Of the three cements failing to show an increase under the autoclave test we find a marked increase in strength at the six-months' period, the average for the three cements at three months being 387 lb., against 455 lb. at six months, or an average gain of 68 lb., for the cement that failed to pass the autoclave test, and it is noticeable that the cement which showed the greatest decrease in strength under the autoclave test showed the most marked increase.

If we accept that there is any relation between the behavior of the test piece under standard laboratory conditions and the behavior of mortar or concrete made from the same cement on the work, the results of the test given by Mr. Force seem to negative his claim, that cement passing the autoclave test will give better results in the work than cements failing to do so.

I do not wish this discussion to be understood as condemning the autoclave test, for I believe it may have possibilities and shall await with interest further reports by Mr. Force and other investigators, which I hope will be coupled with the observation of the behavior of the cement used on the work, but I frankly admit that until such relation is shown I would not recommend the inclusion of the autoclave test in any specification.

A Heavy Rainfall, 10.65 In. in Twenty-four Hours, was recorded at Porto Bello, Canal Zone, on May 14 and 15. This record has been exceeded on the Isthmus only once during the period covered by the commission records. The record precipitation at Porto Bello occurred Dec. 28 to 29, 1909, when 10.86 in. of rail fell in twenty-four hours. The maximum record for forty-eight hours is 16.76 in. and was observed on May 15 and 16. On several occasions records in excess of 10 in. have been observed.

Test for Indicating Relative Priming and Top-Coat Values

The generally accepted conclusion, reached as a result of the experience of the past few years, is that the best protection against the corrosion of iron and steel is not to be secured by the use of any one kind of paint, but by the use of different kinds of paint in combinations. Certain paints are excellent as primers, while others give best service when used as top coatings. The importance of a simple form to determine value of paints in these particulars seems evident. Three years ago Mr. M. McNaughton, of the Joseph Dixon Crucible Company, started a test with this idea in view, and the results seem to show that the method adopted is capable of being used to considerable advantage. He described the method briefly before the meeting of the American Society for Testing Materials in Atlantic City last week. Objection may be made on the ground that the areas covered are too small; but on the other hand, tests of two or more combinations may be made on one piece of steel, thus eliminating uncertainties arising from variations in the qualities of the steel plates.

Briefly the scheme is as follows: The upper half of a steel plate (10 x 16 in. is a good size) is painted with one of the two paints being tested, while the lower half is painted with the other. When dry, the left half of the plate is painted with the first paint and the right half with the second paint. This is the simplest form of the test, and gives four combinations of coats. The plate may be divided into thirds and three paints tested, giving nine combinations of two coats each. In the test referred to two paints were tested on each plate, but three coats were applied, the third coat being a duplicate of the second. The paint was normally mixed and normally spread. The steel was not especially prepared except to see that it was clean. The exposure was in a city, on the roof of a factory, 100 yd. from a railroad, and ½ mile from salt water, and with a southeast exposure.

Mr. McNaughton showed five photographic cuts, not reproduced here. In the first he called attention to the difference in tone of the upper and lower right-hand quarters. This was entirely due to the underlying red-lead coat in the upper quarter, the line of demarcation being its lower edge. The crystalline graphite coating over the red lead had retained its luster, while it had lost it when applied over itself as a priming coat.

In the second view a difference in tone of the right-hand quarters was again caused by the underlying coat of red lead. The other paint used was iron oxide. The upper portion had retained its original brightness, while the lower portion had changed to a dark-brown color.

Another plate, on which white lead and crystalline graphite had been used, showed that no action had occurred between the coatings, as no line of demarcation was observable.

It is quite evident, Mr. McNaughton concluded, that tests made on one plate are much more easily compared than when made on separate plates, with the added advantage of there being no uncertainty as to the character of the metal itself.

The Hydraulic Plant Opposite Culebra installed for lightening the tops of the slides on either side of Gold Hill by sluicing material into the valley behind the hill have been put into operation, according to the "Canal Record." There is an operating force of 114 men.

Experiments on the Action of Various Substances on Cement Mortars

Paper Read before the American Society for Testing Materials at Atlantic City, June 26, by Richard K. Meade, Consulting Chemical Engineer, of Baltimore

The following experiments on the action of various substances on cement mortars were begun some five or six years ago, about the time that the agitation over the destruction of concrete by the alkaline waters of the West was first started, and were undertaken not only to see if such action was really likely to take place, but also to determine which of the salts ordinarily found in ground waters were the cause of such destruction.

The salts usually found in the so-called "alkali waters" of the West are also those which occur in sea water and are those present in largest amounts in many spring and river waters. They are sodium chloride, magnesium sulphate, calcium sulphate, sodium sulphate and sodium carbonate. In order to test the effect of solutions of these substances on cement mortars, a sample of normal Lehigh Valley cement was selected and from it a large number of sand briquettes were made.

Analysis and tests of the cement are given in Table 1.

TABLE 1—ANALYSIS AND TESTS OF THE CEMENT EMPLOYED

Analysis	Per cent
Silica	20.20
Oxide of iron	2.50
Alumina	6.96
Lime	62.40
Magnesia	3.01
Sulphur trioxide	1.60
Loss on ignition	2.38

Physical Tests

SOUNDNESS

Steam	O. K.
Boiling	O. K.
Cold water	O. K.
Air	O. K.

FINENESS	Per cent
Passing No. 100	94.3
Passing No. 200	78.8

SETTING TIME

Initial set	2 hr., 15 min.
Final set	6 hr., 30 min.

TENSILE STRENGTH, POUNDS PER SQUARE INCH

	Neat	Sand
1 day	315	...
7 days	765	245
28 days	875	340
3 months	885	415
6 months	885	435
1 year	890	510

All briquettes were made from a mixture of 1 part cement and 3 parts standard Ottawa sand. They were allowed to harden twenty-eight days in air and then immersed in a solution of the salt. The briquettes were piled in such manner that the solution had access to almost their entire surface.

The solutions in all cases except that of the calcium sulphate, which was a saturated solution, were made up of 1 part of the salt to 100 parts of water, to form practically a 1 per cent solution. At first the solutions were changed every few days, but after the first month the solutions were changed weekly and after the first year less often. The results obtained are given in Table 2.

First it should be remembered that the twenty-eight-day strength of briquettes kept in air is much less than that of those kept in water. As will be seen from the results given in Table 2, the sulphates have a marked action on concrete, which seems to be most apparent in the case of the magnesium salt.

EFFECT OF MAGNESIUM SULPHATE

The action of magnesium sulphate on cement mortars has been discussed quite voluminously of late and I will not go into it to any length in this paper beyond stating that we carefully analyzed the affected portion and the unaffected portion of a sand briquette which had been stored in a solution of magnesium sulphate. These analyses are given in Table 3.

The large increase in the magnesia and sulphur trioxide and the decrease on the oxides of iron and alumina indicate the elements which react with each other. The loss in silica may be due to chemical action also, but as the surface of the briquettes was very much attacked and the sand grains could be scraped away with the finger, I am inclined to think that the lower silica in the disintegrated portion was probably due to mechanical causes rather than chemical action. It will be noted that in almost all cases the first effect of the solution was to increase the strength of the briquettes and that signs of disintegration in no cases became evident until after a period of three months in the solution.

TABLE 2—ACTION OF VARIOUS SALTS ON CEMENT MORTARS

	Tensile strength, lb. per sq. in., after immersion in					
Age in Solution*	Magnesium Sulphate	Magnesium Chloride	Calcium Sulphate	Sodium Sulphate	Sodium Chloride	Sodium Carbonate
0 days	219	219	219	219	219	219
7 days	268	245	227	257	236	225
28 days	272	300	300	334	268	277
3 months	287	315	334	354	299	324
6 months	196	202	314	378	287	320
1 year	Disintegrated	115	209	271	310	337
2 years	...	Disintegrated	Disintegrated	141	325	360

*The briquettes were aged 28 days in air before immersion.

Some of the briquettes were even boiled in a 5-per cent solution of magnesium sulphate for several days, and in all cases the briquettes were much stronger after boiling than they were before and fully as strong as briquettes boiled in pure water, showing how slow the action of the sulphates is.

TABLE 3—ANALYSIS OF A SAND BRIQUETTE; ALL FIGURES IN PER CENT

	Before immersion	Unaffected portion	Affected portion
Silica	75.12	73.96	60.40
Oxide of iron	0.52	0.60	0.30
Alumina	1.15	1.30	0 64
Lime	14.80	14.50	14.21
Magnesia	0.70	1.66	3.64
Sulphur trioxide	0.33	0.83	5.78
Loss on ignition	7.02	7.14	14.97

The briquettes which failed were considerably swollen and presented much the appearance of a baked potato which has burst its jacket.

EFFECT OF BARIUM SALTS AND OF IRON OXIDE

Various authorities have proposed at different times the use of divers ingredients in concrete exposed to sea water, with a view to their reacting with the salts of the latter to form insoluble compounds which would protect the concrete. Most persistently suggested of these are salts of barium, which form with soluble sulphates insoluble barium sulphate. I tried both barium chloride and barium carbonate. These were ground very finely and mixed with the cement. I employed 2 per cent of barium chloride with the cement, and also 2 per cent and 5 per cent of barium carbonate. Sand briquettes were made from these mixtures and the test pieces stored in a magnesium sulphate solution containing 10 grams of the salt to the liter. The results are given in Table 4, and, as will be seen, none of these compounds arrest the destruction.

Some years ago an English chemist suggested the use of finely ground, burnt red brick as an admixture for concrete which was to be used in sea water. After reading this paper it occurred to me that the resistance to sea water claimed for high-iron cements might be due to the presence of oxide of iron in the cement. I therefore had sand briquettes made up containing oxide of iron in various forms and conditions, namely, red or ferric oxide, magnetic oxide of iron, venetian red (an impure oxide of iron made from low grade iron ores, so-called "paint ores" of the Lehigh district), and finely ground red brick, using of these 5 per cent of the weight of the cement in each case and placing the briquettes in a 1-per cent solution of the magnesium sulphate. The results are given in Table 5. As will be seen the additions of iron compounds are in no way beneficial to cements to be employed in sea water.

INFLUENCE OF WATERPROOFING

I next tried waterproofing the mortar on the theory that if the circulation of water through the pores of the mortar could be stopped no chemical action could take place. I employed for this purpose both a high-calcium and a magnesian-hydrated lime, road oil (as recommended by Page), a mixture of silicate of soda solution and fish oil (a well known waterproofing compound), and lime soap (the basis of many waterproofing compounds). I also tried dipping the briquettes first in a hot solution of soap and then in one of alum (Sylvester process). The results of the tests of sand briquettes made from these mixtures and stored in magnesium sulphate solution (10 grams to the liter) are given in Table 6.

TABLE 4—ACTION OF MAGNESIUM SULPHATE ON CEMENT MORTARS CONTAINING BARIUM COMPOUNDS

	Tensile strength, lb. per sq. in., of briquettes containing		
Age in one per cent solution of magnesium sulphate*	Two per cent of barium chloride	Two per cent of barium carbonate	Five per cent of barium carbonate
0 days	181	115	166
7 days	...	221	257
28 days	213	246	346
3 months	306	311	346
6 months	265	204	274
1 year	146	Disintegrated	Disintegrated

*The briquettes were aged 14 days in air before immersion.

TABLE 5—ACTION OF MAGNESIUM SULPHATE ON CEMENT MORTARS CONTAINING IRON OXIDES OF VARIOUS TYPES

	Tensile strength, lb. per sq. in., of briquettes containing 5 per cent of			
Age in 1 per cent solution of magnesium sulphate*	Ferric oxide	Magnetic oxide	Venetian red	Brick dust
0 days	218	225	165	170
7 days	275	280	225	220
28 days	310	340	300	275
3 months	355	340	345	310
6 months	310	280	215	205
1 year	125	105	Disintegrated	Disintegrated

*The briquettes were aged 14 days in air before immersion.

It will be noted that, while the disintegration is evidently taking place in these test pieces, all of these compounds seem to arrest it to some extent at any rate, and in the case of the lime soap and Sylvester process this is quite marked.

ACTION OF MAGNESIUM-SULPHATE ON CEMENTS EITHER HIGH OR LOW IN ALUMINA

I also investigated the action of magnesium-sulphate solution on cements high in silica. For this purpose, samples of commercial cement, one high in silica and low in alumina and one low in silica and high in alumina, were selected; sand briquettes were made of these and immersed in a solution of magnesium sulphate containing 20 grams to the liter, or practically a 2-per cent solution. The cements selected had the following analyses:

TABLE 6—ACTION OF MAGNESIUM SULPHATE SOLUTION ON SO-CALLED WATERPROOFED MORTARS

Age in 1 per cent solution of magnesium sulphate*	Tensile strength, lb. per sq. in., of briquettes containing 15 per cent of hydrated lime (calcium)	15 per cent of hydrated lime (magnesia)	10 per cent of road oil	2 per cent of lime soap	2 per cent of oil-silicate soda	Treated with alum and soap
0 days	215	215	165	185	160	220
7 days	215	225	200	210	200	235
28 days	315	320	210	250	245	275
3 months	245	260	260	275	260	265
6 months	200	245	210	230	225	215
1 year	120	105	140	180	165	185

*The briquettes were aged 14 days in air before immersion.

	Low-alumina cement, per cent	High-alumina cement, per cent
Silica	23.24	19.86
Iron oxide	2.25	2.56
Alumina	5.03	7.60
Lime	63.55	63.12
Magnesia	3.05	3.10
Sulphur trioxide	1.51	1.66

As will be seen from Table 7, the low-alumina cement resists the action of magnesium sulphate much better than the high-alumina one.

In the above experiments both cements were commercial cements; but the high-alumina cement when received was not quite so finely ground as the other one, so it was ground to practically the same degree of fineness in a small jar mill (or to 86.2 per cent passing the No. 200 sieve), so that the fineness of the two samples might in no way influence the results. Both these cements were made from cement rock and limestone.

TABLE 7—ACTION OF MAGNESIUM SULPHATE SOLUTION ON HIGH AND LOW ALUMINA CEMENTS

Age in 2 per cent solution of magnesium sulphate*	Tensile strength, lb. per sq. in., of High-alumina cement	Low-alumina cement
0 days	242	225
7 days	318	307
28 days	404	430
3 months	402	476
6 months	230	472
1 year	Disintegrated	500
2 years	...	425

*The briquettes were aged 14 days in air before immersion.

EFFECT OF SULPHURIC ACID AND OF OIL

In connection with the use of concrete for mine props, where it is often exposed to the action of dilute solutions of sulphuric acid, the following experiment was tried. Sand briquettes were allowed to harden 28 days and then were placed in a solution containing 250 grains of sulphuric acid to the gallon. The solution was changed frequently and the briquettes were broken at regular intervals. The disintegration of concrete by such acid water is shown by the following:

Age in solution—	0 days	7 days	28 days	3 mos.	6 mos.	1 year
Tensile strength, lb.—	226	299	300	280	176	Disintegrated

Several years ago the question of the action of oil on concrete was brought up at one of the meetings of this society in connection with a paper by Professor Carpenter. In his experiments, oil was mixed with the concrete. In the discussion which followed the reading of the paper, a number of gentlemen suggested that what was needed most was information relative to the action of oil on concrete which had already hardened, in view of the employment of concrete for machinery bearings, engine room and factory floors, etc., where it is subjected after being fully hardened to the oil which leaks from the bearings of the machinery. I went home from this meeting and had a number of sand briquettes made and allowed them to harden 2 weeks in air. These were stored in air, in engine oil, in cylinder oil, and in black oil, and broken at stated periods. The results are given in Table 8.

TABLE 8—ACTION OF LUBRICATING OILS ON CONCRETE

Age in oil*	Tensile strength, lb. per sq. in., of briquettes kept in Air	Engine oil	Cylinder oil	Black oil
7 days	248	252	235	234
28 days	233	240	273	222
3 months	287	251	221	181
6 months	303	232	209	131
1 year	293	231	203	Broke in clips

*The briquettes were aged 14 days in air before immersion.

It will be noted that the engine oil and the cylinder oil have practically no effect upon concrete. One would think that as the latter has a considerable proportion of animal oil in its composition it would be apt to appreciably affect concrete exposed to it. On the other hand, the action of the black oil seems strange in view of the fact that it is a straight mineral product. All of these briquettes had absorbed considerable oil, the actual gain in weight of each set at the end of the year being as follows:

In engine oil	10.6 per cent
In cylinder oil	10.0 per cent
In black oil	12.0 per cent

The briquettes in the black oil had not swollen perceptibly and seemed merely to be weak.

SUMMARY

The experiments given above were all made upon very small test pieces and hence the action of the solutions upon them were much more rapid than they would be upon a large mass of concrete; and while in most of the above cases a year was sufficient to completely disintegrate the test pieces, in a large body of concrete such as a pier or wall, many years would be required, at least, to bring about this result. The experiments merely serve to show that even very dilute solutions of the salts of magnesium and the sulphates in general do have a destructive action on concrete and that the generally proposed remedies do not appreciably retard this. They indicate the desirability of employing low alumina cements in sea-water construction. The experiments with the oils show that no destructive action is likely to take place where cement is used for floors in machine shops and engine rooms.

REPAIRING MACADAMIZED STREETS in Marseilles, France, is to be undertaken at an expense of $1,500,000. Granite, sandstone and wood blocks will be used. Paving blocks called "boutisses" may also be used.

Method of Checking Economical Height of Office Buildings

A rational analysis of the problem of proportioning a tall office building so as to provide a profitable investment in a congested metropolitan district, and a mathematical calculation of cost, maintenance, fixed charges and earnings, are given in the following paper presented by Mr. C. T. Coley, M. E., of New York City, at the recent Cincinnati meeting of the National Association of Building Owners and Managers.

Consider the erection of one of the most modern and expensive office-building skyscrapers, the construction of which must be of the very highest grade. The plot of ground should be in the very best location for a building of this kind. Let us assume a land value of $300 per square foot of lot area. The value of a plot of ground is determined by the best possible use to which it can be put, or improvement that can be made thereon to bring in the largest net financial return per annum upon the money invested in the lot. The value of a plot of ground is, therefore, dependent upon its net annual earning capacity; these earnings are usually funded at 5 per cent, making the value of the land about twenty times the net return per annum earned by the land.

The annual interest charged on $300 valuation per square foot would be $15, money worth 5 per cent. The New York City taxes are about $1.83 per $100 valuation, which on each square foot of land under consideration would be about $5.50 per year. This amount added to the interest cost of $15 makes a total cost of $20.50 per year for owning 1 sq. ft. of land in the best financial business district on which to erect a building. If the entire area is not covered by the building, but, say, only 95 per cent of the total, the balance being used for light courts, we must divide the total cost per square foot per annum, $20.50, by 95 cents, giving $21.58, the amount that must be earned per annum on each square foot of land on which the building actually stands. Since only 65 per cent of the area is rentable area, to produce 1 sq. ft. of rentable area we will require 1 divided by 0.65, or 1.54 sq. ft. of floor area, and consequently the land-carrying charge would be increased from $21.58 to $33.23 per square foot of land over which to secure 1 sq. ft. of rentable floor area per floor.

The question arises at once, What can be done to meet this great expense? One answer is, After looking around to see what is suitable for the neighborhood, build a skyscraper office building. What will one cost? How high will it have to be so that the net profit on the building will equal the expense on the land? What will the operating and other expenses be per annum?

Experience shows that office buildings of the very best type of granite, marble, bronze and steel construction cost from 80 cents to $1 per cubic foot of building volume to build. When the average distance between finished floors is 12 ft., it requires 12 cu. ft. of building volume to produce 1 sq. ft. of floor surface, of which past experience shows that in a well-designed building about 65 per cent of the total floor area is rentable area. Therefore, to obtain 1 sq. ft. of rentable area of floor under consideration it will be necessary to build 12 divided by 0.65, or about 18½ cu. ft. of building volume.

Let us assume that we are to build a building about twenty-five stories high, of the type costing 80 cents per cubic foot. It would therefore be necessary to make an expenditure of 80 cents multiplied by 18½, or $14.80 for

18½ cu. ft. of building volume in order to secure 1 sq. ft. of rentable area.

MAINTENANCE COSTS

The costs of maintaining 1 sq. ft. of rentable area per annum in a high class building of this kind are about as follows:

ANNUAL MAINTENANCE COSTS FOR 1 SQ. FT. RENTABLE AREA

Engineer room labor, supplies and repairs	$0.18
Coal and ash removal	.15
Elevator labor, supplies and repair	.09
Janitor's labor and supplies	.15
Electrician's labor and supplies	.02
Supervision and collections	.09
Building repairs	.15
Insurance	.01½
Water	.02½
Sundries	.01
Sub-total	$0.88
Taxes on structure alone	.27
Total per square foot	$1.15

Assume an allowance of 10 per cent of gross rents for vacancies and loss of rent on an average rent rate of $3.50 per square foot, 35 cents, making the total cost of maintenance $1.50. Interest at 5 per cent on an investment of $14.80 necessary to produce the required building volume to secure 1 sq. ft. of rentable area is 74 cents. Allow for depreciation and amortization in 50 years about 30 cents (money worth 4 per cent compounded semi-annually). The total cost per annum, therefore, is $2.54 per square foot of rentable area. Subtracting this cost of $2.54 from the gross rent rate of $3.50 per square root of rentable area leaves a net profit per square foot of rentable area of 96 cents per floor.

In order to equalize or wipe out the annual expense of $33.23 for the lot area on which to build 1 sq. ft. of rentable area we would have to get the profit of 96 cents per square foot rentable area per floor by repeating the operation, or building floor upon floor as many times as 96 cents is contained in $33.23, or 34.6, making the building thirty-five stories.

Hence it will be seen that to develop or improve a plot of land with the value assumed which will pay 5 per cent on the investment in the land and building and at the same time set aside a proper fund for depreciation and amortization a thirty-five-story building will be necessary.

Design of the Woolworth Building

Features of Substructure and Calculations for Wind Bracing of Tower

By S. F. Holtzman, M. Am. Soc. C. E., of Gunvald Aus Company, Consulting Engineers, of New York

The Woolworth Building, at Broadway, Park Place and Barclay Street, New York City, has the distinction of being the tallest building in the world and next to the tallest structure of any kind ever constructed. It is fifty-five stories in height, or 760 ft. 6 in. from the curb to the base of the 22-ft. flagpole, with a basement and sub-basement extending 30 ft. below curb. The total height from sub-basement to the top of the flagpole is 812 ft. 6 in.

The building, as originally designed, was to occupy an area of 197 ft. on Park Place and 102 ft. on Broadway, with a tower of approximately the same dimensions as the present tower on the corner of Broadway and Park Place. The complete design was made for this building, the contract for the foundations let and partially completed and the detail drawings for the steelwork were completed up to the thirtieth floor when additional land was acquired on Broadway and on Barclay Street, giving a site occupying the full Broadway front from Barclay Street to Park Place, 197 ft. on Park Place and 192 ft. on Barclay Street.

A new design was then made for the building with the tower in the center of the Broadway front and a thirty-story wing on Barclay Street approximately a duplicate of the thirty-story wing on Park Place.

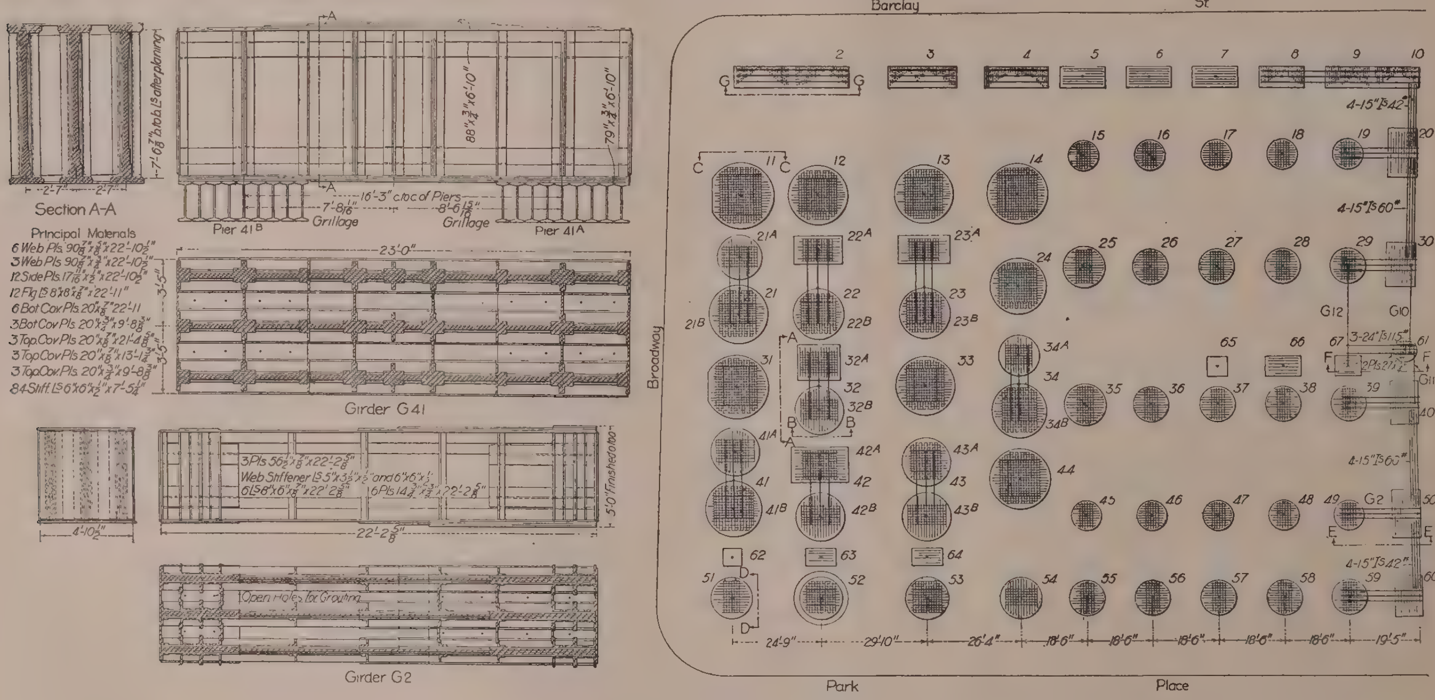
FOUNDATIONS

The foundations for the building are of the usual concrete-pier type, sunk in pneumatic caissons to bed rock which underlies the site at a depth of about 100 ft. below the curb. The piers are of sufficient area to carry the imposed load with a pressure on the concrete of 18 tons per square foot, which with the weight of the piers gives a pressure on the rock of about 24 tons per square foot. The combined length of the piers is about 1 mile.

In the original design all column footings, except on the party line, were designed as independent footings concentric with the columns, in the maximum case extending 5 ft. 9 in. beyond the building line. Between the time of obtaining the permit for the building as originally designed and the filing of application for a permit for the building as finally built a city ordinance was passed prohibiting any foundation from extending beyond the building line. This was interpreted to mean that any new piers sunk on the site covered by the original permit could extend to the maximum projection beyond the building line of any of the old piers but that in the new area acquired the piers must be within the building line. This accounts for the flattening of the outside of the circular piers on Broadway and the use of rectangular piers on Park place.

The wall columns on Park Place and Broadway are set 2 ft. 4 in. in from the building line, but on Barclay Street they were set in 3 ft. from the lot line, which permitted the use of rectangular piers 6 ft. wide, concentric with the columns. The first two columns from Broadway on Barclay Street were balanced on one pier 6 x 32 ft., with spreading girders running the full length. The last three columns on Barclay Street were balanced by spreading girders over two piers and all other columns on Barclay Street were carried on independent piers 6 ft. wide and of sufficient length to take the load at 18 tons per square foot.

The columns on the west lot line were all carried on cantilevers from the adjacent interior columns with rectangular piers 8 ft. wide entirely within the property lines. In the design of piers at the anchor end of these cantilevers the load on them was reduced by the amount of the uplift from the dead load, which in the maximum case amounted to 150 tons. Considerable difficulty was encountered in setting the long spreading girders under the wall columns on account of the shoring braces in place to hold the streets. These had



Typical Cantilever Girders and Plan of Caissons and Grillages for the Woolworth Building to be removed in sections and replaced after the girders were lowered in place.

Work on the foundations was stopped as soon as the new property was acquired, and it was found that the piers for the thirty-story portion on Park Place could be used by the columns for the new design. A number of piers for the tower had been placed and it was found that the columns in the new location would not come over them. There was not room to sink new piers of sufficient size concentric with the columns between the piers in place, so it was decided to make use of the old piers and carry the columns on girders spanning from the old piers to the new ones, sunk as near as possible to them or spanning between two old piers. This accounts for the use of the heavy spreading girders shown on the foundation plan.

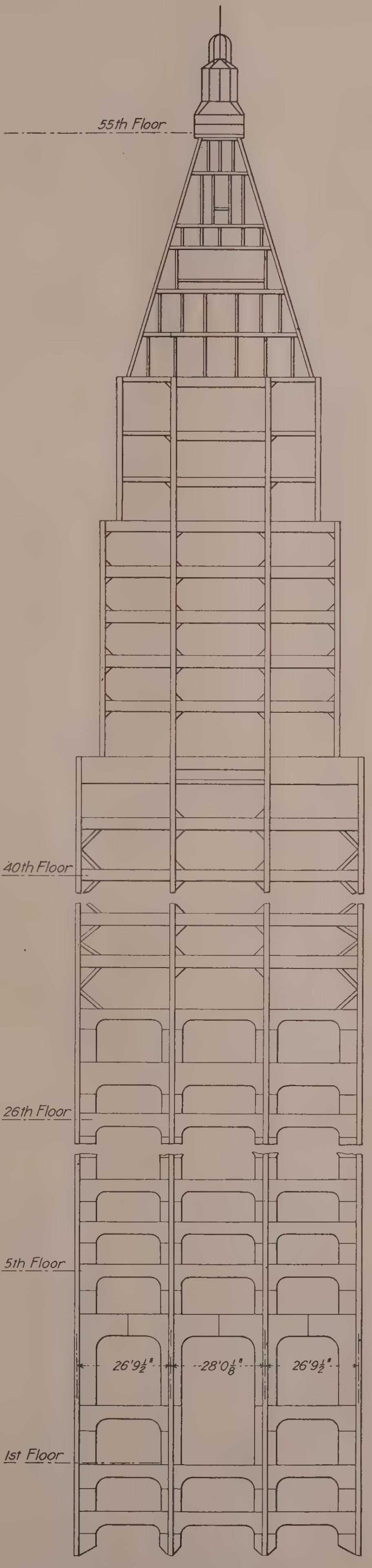
The scheme of spanning two piers necessitated the design of girders almost unprecedented in the matter of loads carried. The heaviest of these girders is that extending from pier 41A to 41B, which is 16 ft. 2⅞ in. center to center of bearings, carrying a column at its center loaded with 4700 tons. This girder is composed of three separate girders, 7 ft. 6⅞ in. back to back of chord angles with flanges of two 8 x 8 x ⅞-in. angles, two 18 x ½-in. side plates and three 20 x ⅞-in. cover plates, with web-plates having a total thickness of 2 in. It was detailed with the web and side plates extended ¼ in. above and below the chord angles; and after the flange angles and side plates were riveted up the three girders were set upon a planing bed and planed top and bottom, taking 5/16 in. from the web and side plates and 1/16 in. from the horizontal leg of the chord angles. This insured a perfect bearing of the castings on the web and side plates. The cover plates were then riveted on. Additional bearing was obtained in the usual manner, with stiffener angles milled to bear tight on the chord angles. The three girders were riveted together with ½-in. diaphragms and shipped complete, weighing about 50 tons. It was found to be impracticable to set this in one piece on account of the shoring, so it was cut apart and each piece set in place and the rivets through the diaphragms redriven.

The general details of the steelwork are not unlike those of other heavy buildings except in the matter of size. The heaviest column, shown in one of the drawings, is heavier than any ever used in building construction; it measures 700.7 sq. in. in gross section and weighs 2500 lb. per foot, including details. This column carried 6,837,000 lb. dead and live load, of which 450,000 was the weight of the column itself and 2,586,000 wind load. The 43½-in. plates extend out to receive the portal bracing, as does the 7 x 1-in. plate on the face. The three webs were detailed the same distance back to back of angles and the center web was riveted to the cover plates; the outer webs were forced into position and riveted. This is a design seriously objected to by structural shops on account of the difficulty of entering the outside webs after the center one is riveted, but no great difficulty was experienced in this case. All the tower columns in the lower stories are of similar design.

Column Bracing

All the tower columns in the lower stories are braced with portal bracing, which introduced no bending moments, but which did introduce additional compression in the column when it acts as the compression flange of the portal. Additional sectional area was provided in all cases to take care of this stress. The columns in the low portion of the building were braced by girders riveted to their sides. These columns, which are of plate and channel section, were designed to stand the full bending moments introduced by the wind in addition to the direct stresses.

The floor construction was hollow tile for all floors except the first floor and basement, which were of 6-in. stone concrete slabs. The horizontal shear due to the wind was assumed to be carried to the streets through the sidewalk construction and the 6-in. slab was used in the first floor to distribute the load from the columns to the sidewalk beams which framed in at this level. The bracing of the tower columns was carried down to the bottom of the columns even though the shear was assumed to be resisted by the sidewalk.



Wind Bracing, Woolworth Tower

Wind Stresses

In a building of this height the resistance to the wind stresses formed a very important part of the design. It was found that in the low portion of the building the wind stresses could be resisted by double girders riveted to the sides of the columns and proportioning the columns to resist the induced bending moments. The wind load was assumed at 30 lb. per square foot for the full height of the building above the curb, with a working stress increased 50 per cent over that used for the dead loads. For convenience in the calculations a stress of 20 lb. per square foot was used and the resulting stresses added to the dead and live load and the combined loads used in designing the columns with the permissible dead and live load unit stresses. No allowance was made for interior partitions in resisting the wind, but the end walls of the building were considered sufficient to resist one-half the wind carried by the line of columns carrying it.

The two wings, or thirty-story portions, were braced together at each fifth floor and were considered to act together in resisting the wind loads. No wind bracing other than the side and court walls was considered in the length of the building, the assumption being that any extra stiffness required in this direction would be carried by the tower.

Design of Tower

The tower was designed to stand alone under full wind load from any direction, no reliance being made upon the stiffness of low portion of the building adjoining.

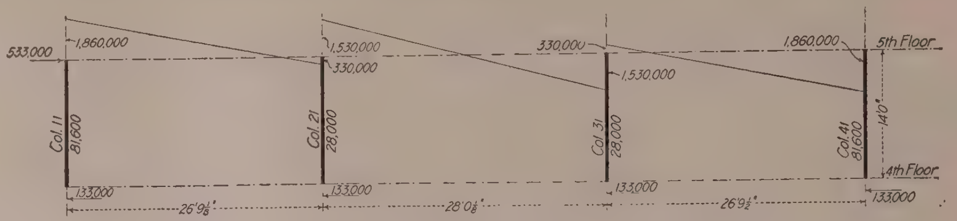
As is usual in all buildings, the steelwork must adapt itself to the architecture, and in this case the type of bracing was used which best fitted the design. Bracing in each bay was used on the Broadway elevation for the full height of the tower, the portal bracing being used in all cases up to the twenty-eighth floor and knee-braces and stiff connections of girders to columns were used above. On the west elevation of the tower bracing was introduced in the three bays from the fourth floor to the top, but below the fourth floor it had to be omitted in the center bay. Full-story X-bracing was used in the two outside bays and the stresses figured, assuming the three bays acting together above the fourth floor and resting on two independent towers from the fourth story to the foundations. No other bracing was used in a north and south direction of the tower, the stresses being assumed to be carried to these two lines of bracing by the floor filling acting as a beam and by the flat diagonal bracing in the level of the top of the floorbeams. No portal bracing could be had in the center bays of lines of columns running east and west through the tower, so only the two outer bays were braced; but this bracing was introduced into the two intermediate lines of columns, thus giving four lines of bracing in the east and west directions up to the twenty-eighth floor. This bracing was figured by considering each braced bay as an independent tower of two columns, thus making eight independent frames to resist the wind in an east and west direction and two frames of three bays each in a north and south direction. Above the twenty-eighth floor the wind was all carried by the bracing in the outside of the tower and the columns designed to carry the resulting moments induced.

CALCULATIONS FOR BRACING

In figuring the stresses in the bracing the assumptions were made that the direct loads in the columns caused by the overturning moment were directly proportional to their distances from the neutral axis of the group and that the horizontal shear or wind load was carried equally by each column of the group. These assumptions are not strictly compatible, but give stresses slightly in excess of the assumption of the shears being unequal and for that reason were used, inasmuch as no assumptions that can be made will give correct stresses when the columns are proportioned to the direct loads and bear little or no relation to the stresses induced by the wind.

The Woolworth Building

This method of figuring, in detail, is as follows: The accompanying diagram represents the fourth-story columns and bracing of the Broadway front of the building. The total wind load at the fifth floor is 533,000 lb. The overturning moment of this frame acting alone, 533,000 × 14 = 7,462,000 ft.-lb. The neutral axis in this case is in the center of the middle bay, and since the vertical stresses in the columns are proportional to their distance from the neutral axis we have, if A = stress at units distance from the neutral axis, the stress in columns 21 and 31 = $14A$ and in columns 11 and 41 = $40.8A$. The resisting moment of these columns = $2\,(14^2A + 40.8^2A) = 7{,}460{,}000$, from which $A = 2000$ lb., $14A = 28{,}000$ lb. and $40.8A = 81{,}600$ lb. These stresses represent the stress introduced in the columns by the action of the wind on this one story. The total wind load on the columns would be the sum of the loads from each story height above, each one acting as an independent frame. The bending moments on the portal bracing are found by assuming the shear to act equally on each column, passing vertical sections through the bracing and finding the resulting moments of the increment of the column loads and the shears acting to the left of the section.



Fourth Story Columns and Bracing, Broadway Front

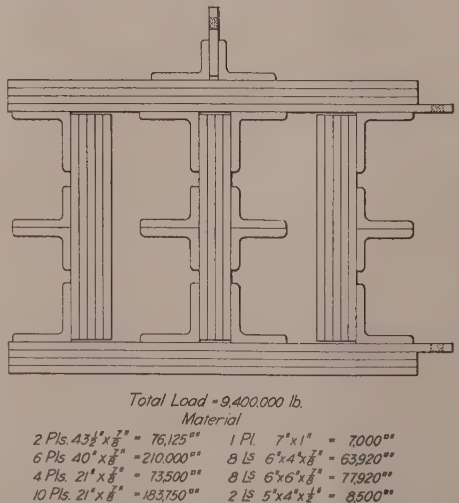
Thus at column 11 the moment, M, = 133,000 × 14 = 1,860,000 ft.-lb. At the left of column 21 the moment = 133,000 × 14 — 81,600 ×26.8 = — 330,000 ft.-lb. At the right of column 21 M = 2 (133,000 × 14) — 81,600 × 26.8 = + 1,530,000. At the left of column 31 M = 2 (133,000 × 14) — 86,000 × 54.8 — 28,000 × 28 = — 1,530,000. At the right of column 31 M = 3 (133,000 × 14) — 86,000 × 54.8 — 28,000 × 28 = + 330,000 and at column 41 M = 3 (133,000 × 14) — 86,000 × 81.6 — 28,000 × 54.8 — 28,000 × 26.8 = — 1,860,000.

These moments are shown graphically and together with the moment from the dead and live loads determine the sections of the portals.

The bracing in the low portion of the building was designed by the same method of figuring and as no portal bracing was used the columns were figured to stand the moment caused by the shear applied at the points of contraflexure taken as the middle point of the unsupported length.

It was found unnecessary to splice any column for either bending or direct tension, as in each case the direct compression stress on the column exceeded the maximum tensile stress.

The building contains 24,100 tons of steelwork, which cost, erected complete, $1,225,000. The cost of foundations, including all shoring of streets and underpinning adjacent buildings, was $1,000,000. The total cost of building was $7,500,000.



Cross-Section of Tower Column

CUBIC CONTENTS AND COST

The cubic contents of the building above the sub-basement floor were 13,200,000 cu. ft., making the cost per cubic foot exclusive of foundations 49.2 cents and cost of steel 9.3 cents.

The architect for the building was Mr. Cass Gilbert and the consulting engineer the Gunvald Aus Company. The foundations were placed by the Foundation Company, the steelwork by the American Bridge Company and the general contract was executed by the Thompson-Starrett Company, all of New York City.

REFERENCE TO FORMER ARTICLES

Other articles on the design and construction of the Woolworth Building have been published in the Engineering Record as follows: General description, May 27, 1911; foundations, August 26, 1911; steel substructure, February 17, 1912; wind bracing, February 24, 1912; method of excavating cellar, April 27, 1912; steel erection, June 27, 1912, and general construction operations, July 27, 1912.

Endurance of Overworked Iron

In the construction of the Manistee River viaduct on the Pere Marquette Railroad it was found that all of the field connections except those of the lateral transverse bracing were bolted instead of riveted, and when the bolts were examined with a view to replacing them by rivets they were found to be in such excellent condition that no changes were made. On the other hand, the connections of the lateral and transverse bracing were found to be in bad condition, many of the rivets being loose and some of them deeply worn by vibrations.

The foreman of erection reported that some of the rivets and old lateral rods appeared harder and more brittle than is usual in such cases, and the test of the upper end of a broken lateral rod showed a crystalline fracture, an ultimate strength of 36,230 lb., an elongation of 3½ per cent in 2 in. and 1.97 per cent of reduction of area at the point of fracture. As this sample was not considered a fair one, two additional samples were cut from load-carrying members in other parts of the bridge, and, being tested, gave a minimum elastic limit of 41,230 lb., ultimate strength of 56,500 lb., elongation of 12 per cent in 2 in., and a reduction of area of 12.2 per cent. This was considered conclusive evidence that no serious injury to the metal had been occasioned by fatigue, although the bridge had been in service for twenty-five years and subjected to consantly increasing loads considerably above those for which it was proportioned. The bridge was fabricated by the Detroit Bridge & Iron Company and was built of wrought iron.

Book Reviews

"Determination of Time, Longitude, Latitude, and Azimuth" is the title of a comprehensive work by William Bowie, chief of the computing division of the U. S. Coast and Geodetic Survey. The book, which is paper bound, 9 x 11½ in. in size and contains 177 pages, is brought out because of the exhaustion of previous editions of a similar work. The subject matter includes most of that in the fourth edition, which is familiar to all students of geodetic surveying, and a number of important additions. The most important of these are the determination of time and longitude, using the transit micrometer; the description of the transit micrometer; determination of time with the vertical circle for use in connection with azimuth observations; a description of the method of observing azimuth coincidently with the horizontal directions in primary triangulation; an example of the determination of an azimuth in Alaska with a transit equipped with a transit micrometer; examples of the records and computations in the different classes of work as actually made by the Survey; and statements of field cost. (Washington, D. C., U. S. Department of Commerce.)

"San Francisco Relief Survey" is an attempt to bring together such data regarding the relief work after the San Francisco disaster of 1906 as will be of value in organizing the relief work following other great calamities. Naturally the organization of an adequate relief service of sufficient magnitude to care for the homeless and suffering after such a visitation is a tremendous task, and looking back on their experiences the authors find much that can render future work of this sort the more effective. The book is divided into chapters on the organization of the force and the emergency methods, business and housing rehabilitation, relief work of the associated charities (extending from June, 1907, to June, 1909), the residuum of relief (the aged, infirm and the handicapped) and a succinct summary of the lessons learned. (New York, Survey Associates, Inc., $3.50 postpaid.)

"Measurement of Irrigation Water," by F. H. Newell, director, is the title of a pamphlet published by the U. S. Reclamation Service. The first part deals with different types of measuring weirs and with formulæ for the determination of the discharge, construction, installation and care of weirs, etc. The last twenty-two pages contain tables from which the discharge over weirs in second-feet can be obtained, providing the head on the weir and the length of the weir are known. There are also tables giving the number of acre-feet when the discharge per second for a given time is known.

A description of methods of purifying water for drinking is given in a report by George A. Johnson, just published by the U. S. Geological Survey. The report describes the various types of water supply systems used by cities in the United States, sets forth the principal advantages and disadvantages of each, and gives a brief history of the development of waterworks systems and the effect of their installation on the health of communities. The paper includes a historical sketch of systems of water purification, from the storage works and clarification by alum used by the ancient Chinese to the present-day methods of filtration, coagulation and sterilization. Preparatory treatment, in which the water is passed through sedimentation tanks, coagulation basins, or roughing filters to remove a portion of its color or turbidity, is discussed in detail. The softening of municipal water supplies in connection with their purification is discussed. In the report technical terms have been avoided so far as possible and the subject-matter presented so that it can be understood by the non-technical reader. It contains much information of value to city officials, boards of health, and others interested in sanitary engineering as applied to waterworks planning, construction, maintenance, and operation. It is published as Water Supply Paper 315, and a copy can be obtained free of charge on application to the Director, United States Geological Survey, Washington, D. C.

European Cities at Work. By Frederick D. Howe, Ph.D. Cloth, 5½ x 8¼; 385 pages. New York, Charles Scribner's Sons, $1.50 net.

The German city, Dr. Howe says in his introduction to this book, is an experiment station, a little republic with power to do anything for the welfare of the people. Evidently with this thought in mind the greater part of the volume is devoted to municipal administration in Germany, although about seventy-five pages are devoted to municipal conditions in England. As might well be suspected, considerable space is given to the municipal and engineering works, so that the volume has an especial interest to municipal engineers who are looking at their work broadly. Aside from its indirect interest, because of its reference to engineering work, it should be of special interest to engineers because of the present tendency to call upon them to assume larger responsibilities in municipal administration. This requires knowledge not alone of engineering, but of the whole problem of civic development, civic betterment and methods of municipal administration. It has long been recognized that in these respects European cities are in advance of those of the United States. Some of the titles of chapters in the volume will be suggestive of the scope: Town Planning and City Building, The Housing Problem in Germany, Socializing the Means of Transit, The Budget of the German City, How the German City Is Governed, The Business Men Who Rule the German City and Their Ideals, and finally The American and European City—A Comparison. The volume, written by an investigator with long experience in these matters, should, therefore, prove of much interest to municipal engineers.

Magneto and Electric Ignition. By W. Hibbert. Cloth, 4¼ x 6½; 154 pages; 90 illustrations. New York and London, Whittaker & Co., 80 cents net.

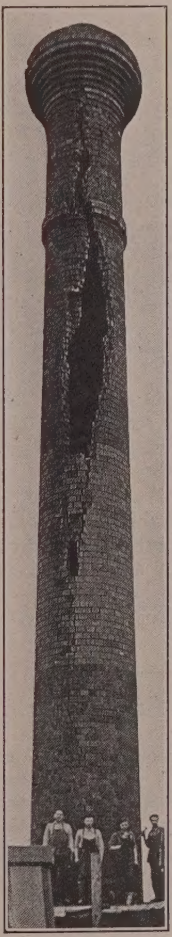
This little manual is one in the series of Practical Handbooks, and should be a useful book for those who operate internal-combustion engines, as well as for those interested in the general principles of electric ignition. The occasional attempts at introducing somewhat abstruse scientific principles, such, for example, as the explanation of the flow of current according to the electron theory, are amusing and merely add to the zest of reading the book.

The introductory chapter is not well done, being far from clear and its arrangement being illogical. It is not simply put, does not explain, and might with advantage be omitted. Chapter II treats of the High-Tension Magneto and is well done. Some of the cuts, however, are much too small for clearness. Chapter III, on Faults, and Their Remedy, is rather too brief to be broadly useful. Chapter IV, on Gearing, is particularly good.

The remaining chapters, on Other Magnetos, Ignition by Battery and Coil, Faults in Cells and Combinations, are worth while, although here again the cuts might frequently be improved so far as clearness is concerned. One can hardly expect a book which refers to automobile development to be up to date, and in this respect one is not disappointed with the present volume. The Dual Systems and Recharging Methods receive an absolutely inadequate treatment.

Letters to the Editor

Chimney Struck by Lightning



Dear Sir: The 5 x 135-ft. brick stack serving the heating plant of the two factories of M. T. Silver & Company and the Sunshine Cloak & Suit Company, Cleveland, Ohio, was struck by lightning during a heavy thunderstorm that passed over the city on the night of June 19. The lightning struck the stack just below the brick astragal and cut a gash in the side 60 ft. long down to a point just below where the men are standing. This gash has a maximum width of 3 ft. A loose piece of brickwork is hanging in the gash just above the smaller opening. The largest portion of the wreckage fell through the roof and skylights of the M. T. Silver factory, but some pieces were thrown more than 70 ft. to the street in front of the building. The damage is estimated as $5000. The upper 60 ft. of the stack will have to be torn down. A scaffold is being erected for this purpose. No one was injured. The chimney was not protected by a lightning rod.

A. D. Williams.
Cleveland.

Stresses in Circular Tubes

Dear Sir: In the issue of June 14 are given some formulæ for stresses in circular tubes; the formulæ look handy and will undoubtedly be of considerable use.

The article mentions the scarcity of publications on the subject. Would it not have been proper, then, to devote some space on another part of the subject, the one about the loadings, which may occur? The common theories about earth pressure are pretty easy to apply when a retaining wall is concerned, but when we get to a subterranean tube the question gets intricate, to say the least. For instance, how will a concentrated load on the ground level act on the tube? Which proportion of the overhead fill will be carried by the tube and which by the internal friction and arching effect in the fill? In the last instance the loading will depend upon the method of construction and especially of excavation and backfilling.

There are theories about this, but on account of the difficulty of effective tests they are not much more than theories. Some information about the loadings assumed by the Public Service Commission in New York City would be of interest to engineers designing this kind of structures.

New York. W. Poulsen.

[Mr. Haukelid, the author of the article referred to, is abroad at present. Upon his return to this country he will doubtless be glad to reply to the questions raised by Mr. Poulsen.—Editor.]

Rating the Efficiency of Municipal Employees

Dear Sir: In your issue of June 14 appears an article entitled "Rating the Efficiency of Municipal Employees." As an engineer of several years' experience with both railroads and cities, I wish to protest against the common assumption under civil-service conditions that men are machines. The man who is fined for being a minute late will never work overtime except under compulsion, nor will he take any but a "bread-and-butter" interest in his work. A far better way is to abolish all clocks from the office and let the men come to work as near the established time as they want to. Some will come before the regular hour, some on the hour, and some late. Promote the first class, if their habit is chronic; say nothing to the second, and discharge the third if no improvement appears. Even the man who comes late often works late when he knows his work is appreciated. Joy in human labor is one of the finest things in life, and one of the easiest to kill when treated by efficiency experts as outlined in your article.

Geo. L. Davenport, Jr.

Los Angeles.

Licensing of Engineers

Dear Sir: Since his letter published in the Engineering Record of May 17, page 563, the writer has read with interest the accounts thereon and has found nothing to change his opinion regarding the protection to be afforded either the profession or its clients by the general proposal to license engineers.

Replying to Mr. Walter H. Drane's letter of June 7, the writer begs to point out that Mr. Drane seems to ignore the method of protection suggested by the writer in his letter of May 17. It certainly would seem that such a method would be an actual license or permit for the consummation of each individual piece of work affecting the public of each and every engineer.

Which is the surer means of control—to license a man to design and construct engineering work generally or in detail and then turn him loose with little or no further scrutiny of his projects, or to forego the original license and require him to submit each project to competent judges for approval as to essential features of safety, etc.?

The statement of Mr. Drane regarding the writer's "error" as to the real purpose of license laws would seem to be due to a misunderstanding or a too hasty perusal of the letter referred to. Practically all of it except a portion of the last paragraph was devoted to the subject of the license scheme as it affected the safeguarding of engineers' clients and the public. The writer must still refuse to agree with Mr. Drane in regard to the latter's view of the likeness of the medical to the engineering profession; he cannot see the analogy between the two practices in the license problem, and further he cannot see how the license proposition would protect the profession against the type of "job hunter" so bitterly assailed by Mr. Drane. As frequently pointed out, these "engineering sharpers" are often perfectly equipped and trained in the practice of engineering and, in nine times out of ten, would be as well able to procure a license as any one else. The method of gaining clients does not seem to have any large part in this discussion. No law can bar a man from the profession simply because he is unethical or will work for low fees.

The writer does not intend anything he has said in this discussion to be construed as decrying technical training—we all need more of it.

E. G. Kastenhuber, Jr.

Vineland, N. J.

Use of Hydraulic Lime for Masonry Dam

Dear Sir: The description of the use of a cement prepared from hydrated lime and roasted clay appearing in your issue of June 14 under the title "Use of Hydraulic Lime for Masonry Dam" should be of considerable interest to engineers and contractors carrying on large work in regions distant from a supply of Portland cement.

We, however, would take issue with the author of this paper in his use of the term "hydraulic lime." The term "hydraulic lime" is generally accepted to imply an argillaceous lime which will slake to a dry flocculent powder on the addition of water, which contains sufficient silicious and aluminous material to cause it to harden under water. Since hydraulic limes slake on the addition of water, the lime content as a matter of course must be high, averaging in the hydraulic limes of France about 80 per cent in the burned rock before slaking.

The cement described in the article consists of 1 part hydrated lime and 1 or 2 parts of roasted clay. The lime content is, therefore, comparatively low, ranging from 25 to 35 per cent in the finished cement. We would, therefore, consider these cements as true Puzzolan cements, rather than hydraulic limes. It would seem that they would be classified with the Puzzolan cements of southern Europe, which consist of 1 part slaked lime and 2 parts volcanic ash, and with the trass cements of Holland and Germany, which consist of 1 part slaked lime and 2 parts trass.

For certain purposes there is no reason for hesitation on the part of the engineers to use these Puzzolan cements. Hydrated limes of excellent quality are obtainable in most sections of the North American continent, and clays or shales which are suitable, either in their natural state or after roasting, are very prevalent. The preparation of such a cement requires a small outlay for machinery, etc. For the laying of masonry, certain foundation work, etc., such cements are eminently suitable. Some years ago in California we encountered a clay which when mixed in the proportions of 2 parts raw clay and 1 part hydrated lime gave strengths practically equal to those of Portland cement.

The most vital step in the preparation of these cements appears to us to be the thorough incorporation of the various ingredients. In the case described the hydrated lime, clay and sand were incorporated by pug mills, the consistency being such that the rollers actually ground the ingredients together. We believe that this use of hydrated lime will come in for considerable attention in the near future.

Henry S. Spackman
Engineering Company,
E. L. Conwell,
Philadelphia. Secretary.

Dry Rot in Floors

Dear Sir: There has recently come to the attention of the writer an instance of dry rot in the wood floors of a mill-constructed warehouse which appears to be of a nature deserving the attention of owners, architects and engineers of such structures.

The floors concerned were constructed of 2 x 6-in. joists placed on edge, side by side, and spiked solidly together, spanning between large wood girders and covered on top first with one layer of 30-lb. asbestos paper, next with one layer of waterproof paper, and finally with a ⅞-in. square-edged finished floor.

The building had never been heated since its completion and was not plastered. The ceilings, posts and girders had been sprayed with some sort of cold-water paint, but not whitewash. The building was completed in June, 1911; hence, at the time the dry rot was discovered the building was slightly less than two years old. It is located on a sand-filled flat within 200 or 300 ft. of salt water. The building is approximately 100 ft. square and three stories high; the walls are of concrete, and the structure has been used for storage of grain since its completion.

The dry rot was discovered when occasion was had to remove several panels of one of the floors. Upon removing the finished floor and the waterproof paper it was discovered that the asbestos paper, in contact with the underflooring, was in some places completely saturated with moisture and in all places was quite damp. The underside of the paper was covered with fungi, as was also the top of the underfloor, although the amount of the growth varied greatly in different portions of the floor. The fungus had grown in finger-like form along the top and downward between the members of the laminated underfloor, the fingers, in many instances, being 4 or 5 in. long.

The growth seemed to be somewhat at random, although it appeared that sappy joists were attacked more severely than were the others, and that the tendency seemed to be more apparent at the ends or splices of the joists and also immediately over the girders. The joists did not seem to be affected in the lower half or two-thirds of their depth. Fortunately the decay had not progressed to an extent necessitating the replacement of the underfloor.

Samples of the fungus was taken by Dr. H. K. Benson, professor of industrial chemistry in the University of Washington, and were planted in a pure culture. The fungus developed rapidly and grew very profusely, showing that it was still very much alive and that steps would have to be taken immediately to eradicate the fungus in the warehouse and to remove its food supply.

With the consent of Dr. Benson, the latter's statement of his conclusions relative to the causes of the fungus growth and the means of eradicating same are quoted as follows:

"My theory as to the trouble is that when the floors were put in place the water moved downward by capillarity along the 2 x 6's toward the surface exposed to the air, and this seasoning reached for some distance toward the upper part of the 2 x 6's. Here, however, dry asbestos was placed, and the absorptive power of the asbestos for water being greater than the capillarity of the wood, a portion of the moisture traveled upward and was absorbed by the asbestos. Consequently the asbestos became a moist field in which fungi developed and spread for their food supply into the wood underneath, devouring the cells of the wood and producing what is known as dry rot.

"The remedy I propose is to remove the flooring, tear off the asbestos and allow the floor to season for a week or ten days, after which the spores should be killed by some proper sterilizing fluid.

"For this purpose I recommend a liquid having a fluidity similar to that of turpentine, viz., a specific gravity of about 0.85. Liquids suitable for this purpose are the high boiling fractions of coal tar, diluted with petroleum distillate to the density above mentioned; or the commercial mixture of tar oils, known as firoleum, diluted to such density; or avenarius carbolineum, diluted to a similar density.

"Using a highly fluid preservative of this type I think you will find that the heavier oils will be carried by the diluting oils into the pores, cracks and crevices, and kill the spores, as well as render the cells unfit for food purposes for the fungi.

"In regard to future construction along this line, it seems to me that modes of construction should be changed. First, there should be an air space between the 2 x 6's, so as to carry away the moisture during the drying out or seasoning period, and second, no highly absorptive material, such as asbestos, should be placed upon a wooden surface unless the same has first been well seasoned and is free from moisture."

Since the discovery of the dry rot mentioned two or three similarly constructed buildings in this city have been examined, including one building which is heated and plastered and which has laminated solid-wood-slab floors. The examination has not been thorough enough as yet—that is to say, enough buildings have not yet been examined—to justify the writer in believing that similar instances of dry rot may not be found. The writer has been told by two architects of this city that they have each known of one or two cases where buildings of the same construction were rendered so unsafe by dry rot as to necessitate the entire reconstruction of the floors. They ascribed the dry rot, as does Dr. Benson, to the presence of the asbestos paper in contact with the upper face of the underfloor. It is hoped that any of the readers of the Engineering Record who may know of such instances will communicate them to the editor so that further light will be thrown on the matter.

As the writer understands it, the growth of the dry-rot fungus is not fostered either by cold or by warmth, the most favorable temperature being about 50 deg. Fahr. Dry rot would, therefore, seem to be improbable in heated buildings used as places of habitation, in which the temperature is ordinarily kept in the neighborhood of 70 deg. Whether the plastering of the underside of solid wood floors would foster the growth is somewhat problematical. Usually plastered buildings are heated, but if this were not the case it is thought the plastering would encourage the growth. Commercial plasters are usually very much less porous than old-fashioned lime plasters and would probably confine the bases occasioned by the drying out of the floors and foster the fermentation of the sap in the wood. There seem to have been a number of cases where large timbers, encased in hard plasters, were damaged or destroyed by dry rot.

The building ordinances of this city have for many years required that in mill constructed floors the asbestos paper be provided. Originally the ordinances did not specifically mention or cover the construction of floors built of joists on edge, spiked solidly together; the ordinances covered only the more prevalent type of floors built of 2 or 3-in. tongued and grooved planks, spanning between heavy joists. When the laminated floor construction first came into use in this city the superintendent of buildings ruled that the asbestos paper could be omitted in such floors 6 in. or more in thickness. Consequently most of the buildings in this city having laminated floors do not have the asbestos. Recently, however, a revision of the ordinance resulted in a mention of laminated floors and the requirement of the asbestos paper was imposed as to these also. Since the discovery of the dry rot to which this letter refers this requirement has been eliminated, both as to laminated and plank floors, but the waterproof paper is still required.

In connection with this matter expressions of opinion as to the efficacy of asbestos paper in preventing the spread of fire might also be interesting.

D. E. HOOKER,
Assistant Superintendent of Buildings.
Seattle.

[It is conceded by such authors on building construction as Johnson, Allen, Thurston and Kidder that dry rot can be blamed almost entirely on lack of ventilation. Incomplete seasoning enters into the matter only to the extent that unseasoned wood will rot in spite of ventilation, while perfectly seasoned wood will withstand lack of air if it can be kept perfectly dry. Good ventilation will, however, preserve and gradually dry out wood not thoroughly seasoned.

Dr. Benson's theory as to the cause of the warehouse trouble seems to be correct, as well as his suggestions as to future construction. Air spaces between the 2 x 6's, with openings at the end, would presumably have prevented the rot mentioned. Heating the building apparently would not, as dry rot takes place in buildings at ordinary office temperature. It will be a matter of interest, if the sterilizing fluid is used, to know whether or not it kills the growth. The authors on the subject state that dry rot, once started, spreads rapidly, passing readily from timber to timber, and some of them advocate complete removal of the affected portions as the only remedy.

A case different from the one mentioned shows the difficulties connected with wood floors in concrete buildings. The cinder-concrete slab was covered with a false wood floor laid on nailing strips between which concrete had been placed, and on the false floor was laid the finished maple floor. A few months after the completion of the structure the entire floor was covered with heavy linoleum, thus putting on a seal which prevented the escape of excess moisture in the cinder-concrete fill and the flooring. Two months after the linoleum was laid the floor began to swell and buckle into humps. The linoleum was removed and the flooring found in places to be badly attacked by fungus. The buckled boards and decayed portions were replaced by new flooring and the linoleum relaid. The trouble recurred, however, and finally after much patching of the floor the entire covering was removed, allowing the wooden floor to be exposed for about a year. This evidently sufficed to dispel the moisture, because the linoleum was afterward relaid and, though several years have elapsed, no further difficulty has been experienced.—EDITOR.]

Bending Strength of Yellow-Pine Timber

Dear Sir: Reference is made herein to an article in the Engineering Record of May 31, 1913, page 608, by Mr. J. J. Morgan, consulting engineer, Columbus, Ohio.

The comparisons of nominal and standard or actual size timbers of yellow pine, the section moduli, etc., are substantially as given in the handbook issued in 1911 by the Yellow Pine Manufacturers' Association and prepared by the writer. A new edition, entirely rewritten and enlarged, is in press and will soon be ready for distribution to those requesting copies.

Exception is taken to a statement made by Mr. Morgan as to the factor of safety and to the allowable fiber stress used.

The statement mentioned reads: "Most of the yellow pine on the market in the Central States is of quick-growth variety and for permanent work should not be loaded so as to produce a fiber stress in excess of 1000 lb. per square inch. However, for temporary work, such as forms for concrete construction, if the timber is of good quality the loads in the tables may be used for quick-growth yellow pine, thus giving a factor of safety of 5. For permanent work where this pine is used the values in the tables should be multiplied by 5/6."

As to the quality of yellow pine on the market in the Central States, Mr. Morgan is in error. Statistics as to the origin and distribution of the shipments of yellow pine for the years 1910, 1911 and 1912 have been furnished by Mr. George K. Smith, secretary of the Yellow Pine Manufacturers' Association, St. Louis. The States to which these shipments were made are New York, Pennsylvania, New Jersey, Ohio, Indiana, Michigan, Illinois, Tennessee, Kentucky, Wisconsin, Minnesota, Iowa, Missouri, Nebraska, Kansas, Colorado, South Dakota and Oklahoma.

The States of Missouri, Arkansas and Oklahoma produce the bulk of the short-leaf yellow pine, and it is apparent from the above table that the shipments originating in these states amount to 29.01 per cent of the whole amount considered and that 70.99 per cent originated in the long-leaf yellow pine States.

Under date of Jan. 20, 1913, the Bureau of Corporations, Department of Commerce and Labor, issued a report entitled "The Lumber

ORIGIN OF SHIPMENTS OF YELLOW PINE

Origin	1910		1911		1912	
	Feet	Per cent	Feet	Per cent	Feet	Per cent
Missouri and Oklahoma	70,090,038	2.73	63,858,283	3.09	98,557,818	4.71
Arkansas	618,247,489	24.06	534,002,911	25.87	555,857,457	26.57
Texas	431,350,828	16.79	327,879,476	15.88	345,213,353	16.50
Louisiana	891,145,194	34.68	640,444,744	31.02	644,976,170	30.83
Mississippi	319,817,726	12.45	297,847,923	14.43	266,457,765	12.74
Alabama	217,341,713	8.46	175,133,810	8.48	155,507,257	7.44
Georgia and Florida	21,402,727	0.83	25,346,335	1.23	25,352,124	1.21
Totals	2,569,395,715	100.00	2,064,513,482	100.00	2,091,921,944	100.00

Industry—Part I, Standing Timber." Referring to the amount of virgin standing timber the report (page 11) states:

"The predominating species in this Southern pine region is yellow pine, which contributes 384.4 billion feet (232.3 billion feet long-leaf and 152.1 billion feet short-leaf and loblolly) to the total of 634 billion feet; cypress, 40.4 billion feet; and all hardwoods together, 209.2 billion feet. The hardwoods include the least valuable timber in this region."

By the term "quick-growth variety" Mr. Morgan probably intends to describe the second growth of Oldfield pines. Trees of this growth do not produce what would be termed structural timbers that are worthy of the attention of the engineer and at best could only produce the smaller sizes of joists and scantlings such as are used in inferior structures. The bulk of the short-leaf cut is manufactured into finishing lumber and products other than structural timbers, this being more profitable to the producer. The virgin timber exists and is being manufactured and shipped into the Central States.

The writer has questioned architects and engineers in Chicago and St. Louis whose practice comprehends the annual consumption of millions of feet of yellow pine and finds no complaint whatever as to the quality of this material furnished for their work. Where complaints have been investigated it has been found that they increase directly as the amount of this material used decreases, and some of the most radical complainants never used 1,000,000 ft. of lumber in their practice. If a buyer receives mercerized cotton instead of the silk purchased you cannot cast reflection on the genuine silk, but rather charge it to the buyer's ignorance—and the same is true as to yellow pine.

As to factors of safety, permit a quotation from Circular 15, Forest Service, U. S. Department of Agriculture:

"As to factors of safety, it may be proper to state that the final aims of the present investigations may be summed up in one proposition, namely, to establish rational factors of safety. It will be admitted by all engineers that the factors of safety as used at present can hardly be claimed to be more than guesswork. There is not an engineer who could give account as to the basis upon which numerically the factors of safety for wood have been established, as '8 for steady stress; 10 for varying stress; 15 for shocks' (see Merriman's 'Text Book on the Mechanics of Materials'); or as 4 to 5 for 'dead' load and 5 to 10 for 'live' load (see Rankine's 'Handbook of Civil Engineering').

"The directions for using these intermediate factors of safety given in the text books would imply that the student or engineer is, after all, to rely on his judgment as to the modification of the factor; i. e., he is to add to this general guess his own particular guess. The factor of safety is in the main an expression of ignorance or lack of confidence in the reliability of values of strength upon which the designing proceeds, together with an absence of data upon which to inspect the material."

There is no valid reason why wood, and especially yellow pine, should be used with a factor of safety of 6 and more. It is the only structural material whose defects are apparent on superficial inspection, and the effects of defects are so well known to intelligent users of timber that the strength of the timber can be easily judged. Engineers design reinforced-concrete work and for the constituent parts use factors of safety ranging from 2 to 3½. On completion of the work a test is the only index as to its strength, for superficial inspection tells nothing. Wood construction could be subjected to the same tests if necessary.

There is sufficient valid information in existence concerning the physical properties of yellow pine to justify fiber stresses as follows:

	Long leaf	Short leaf
Compression with grain	1800	1500
Compression across grain	350	275
Shear with grain	175	150
Extreme fiber stress	1800	1500

For columns the following is recommended:

For long leaf	15 $(1-l/80d)$
For short leaf	1200 $(1-l/80d)$

In addition to the known physical properties of yellow pine is the long and unequaled record of this material used with these stresses and involving no collapses or failures, all of which should be considered by the engineer in arriving at intelligent conclusions. In the construction of the buildings for the Louisiana Purchase Exposition in St. Louis Mr. P. J. Markmann, C.E., chief engineer of construction, used an extreme fiber stress of 1800 lb. per square inch and 400,000,000 ft. of this material was used.

From Bulletin 108, U. S. Forest Service, it is found on segregating those failures by tension or compression from the failures by horizontal shear that the average ultimate fiber stress for the first-mentioned failures is as follows:

Long-leaf yellow pine, green	6348
Long-leaf yellow pine, air dry	7658
Short-leaf yellow pine, green	5519
Short-leaf yellow pine, air dry	6487
Loblolly yellow pine, green	5031
Loblolly yellow pine, air dry	5725

These timbers were not graded but tested as they came from the log without reference to defects. Bulletin 41, Engineering Experiment Station, University of Illinois, by Prof. A. N. Talbot, states that the average ultimate fiber stress for long leaf yellow pine is 5308 lb. (19 per cent moisture) and 5470 lb. (26.6 per cent moisture). It is stated that some of the pieces tested "would hardly be called merchantable sticks." From the above it is apparent that the strength of graded timbers would be much higher.

In 1895 the American Association of Railway Superintendents of Bridges and Buildings (now the American Railway Bridge and Building Association) adopted the following as safe extreme fiber stresses for railway bridges and trestles:

Long-leaf yellow pine	1200 lb.; factor of safety 6
Short-leaf yellow pine	1000 lb.; factor of safety 6

The data and discussion upon which this schedule was based form one of the most valuable contributions to timber engineering that exist.

In 1909 the American Railway Engineering Association (see "Manual," 1911, and "Proceedings," Vol. 10, Part I) adopted a schedule of working stresses on extreme fibers intended for railway bridges and trestles, as follows:

	Average ultimate	Working stress
Long-leaf yellow pine	6500	1300
Short-leaf yellow pine	5600	1100

From the discussion on page 610 of "Proceedings," Vol. 10, Part I, the following remarks by Professor Jacoby of Cornell University are taken:

"Before voting on the motion relating to this conclusion I wish to make a statement on the necessity for a note to accompany the table of unit stresses when printed in the 'Manual,' and for this reason: We all remember when the excellent report of 1895 was made by a committee of the American Association of Railway Superintendents of Bridges and Buildings, of which the late Mr. Berg was chairman, that the part of the report on unit stresses in the form of two tables was copied very widely, being published in handbooks, text books and engineering periodicals throughout the world, and in many cases these results were used in a different way from that intended by the committee. It seems, therefore, desirable when this table is published in the 'Manual' that a note should accompany it calling attention to certain points, so that it will not be used in a manner different from that intended by the committee." The note reads as follows:

"The working unit stresses given in this table are intended for railroad bridges and trestles. For highway bridges and trestles the unit stresses may be increased 25 per cent. For buildings and similar structures in which the timber is protected from the weather and practically free from impact the unit stresses may be increased 50 per cent. To compute the deflection of a beam under long-continued loading instead of that when the load is first applied, only 50 per cent of the corresponding modulus of elasticity given in the table is to be employed."

On the table it is noted that "these unit stresses are for a green condition of timber and are to be used without increasing the live load stresses for impact."

The "American Civil Engineer's Pocket Book" uses the above-mentioned stresses, adopted in 1895, but in a footnote advises an increase of 20 per cent for highway bridges and trestles and 30 per cent for protected timber, as in a building.

A careful reading of Professor Jacoby's remarks gives a clue to the birth of the 1200-lb. fiber stress for buildings, conceived by the stupidity of engineers who could not differentiate between a stress applicable to railway bridges and trestles and a stress suitable for a building. Imagine an all-steel train drawn by a Mogul locomotive safely crossing a trestle designed with a 1200 or 1300 lb. fiber stress and then, perforce, using a 1200-lb. fiber stress in designing a blushing bride's bungalow.

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PUZZOLAN CEMENT was manufactured during 1912 at three plants in the United States—at North Birmingham, Ala.; Struthers, Ohio, and Sharon, Pa.—and "Collos" cement at Buffalo, N. Y., according to the United States Geological Survey. The output of Puzzolan and "Collos" cements in 1912 was 91,867 bbl., valued at $77,363, compared with 93,230 bbl., valued at $77,786, in 1911. The average price per barrel of these slag cements in 1911 and 1912 was 83.4 cents. In 1912 the average price of slag cement was 2.1 cents higher than that of Portland cement. One reason for the present high average price of Puzzolan cement is that a considerable quantity of this product is of a light color and is considered to be non-staining and consequently is sold at a higher price than ordinary gray or brown cement.